2.9 OFF-BOARD DECEPTIVE ECM

ECM off-board deceptive jamming as used in the ASPs for ESAMS is noise or other jamming signal sources that are not located on the target aircraft. It includes chaff and towed decoys which may have significant effectiveness in decoying target tracking radars and missile seekers. Both of these techniques present false targets to the victim radar which can draw tracking radars and missile seekers off the intended target. Chaff clouds, which consist of strips of electromagnetic reflectors, can be particularly effective against older radars which are not fully coherent. Similarly towed decoys with repeaters using a variety of techniques can draw missiles away from the aircraft and enhance target aircraft survivability from many engagement geometries. ESAMS models chaff and towed decoys. Each is discussed below.

Chaff

The purpose of chaff as modeled in ESAMS is to present a false target to the missile and prevent aircraft intercept. The chaff cloud is illuminated by the illuminator radar. The return from the chaff cloud presents an alternative target with a stronger signal to the tracking radar either on the ground or the missile seeker. Effective chaff will cause the missile to be guided to the return signal from the chaff cloud rather than to the target aircraft

Chaff consists of light metal strips (typically glass fibers coated with zinc) which reflect radar signals back to the receiving tracking radar. Being extremely light they hang in the air for a long time and billions of them can be stored in a small space and used to create a cloud which returns a strong radar signal. Chaff can be deployed by ejecting bundles from the aircraft in any direction including forward launching to create radar signals all around the aircraft concealing the true aircraft location. To be most effective, chaff is cut in lengths equal to the wavelength of the radar(s) being jammed. Chaff cut to wavelengths different from that of the illuminated radar still has some effectiveness, but at a reduced level.

To represent the characteristics of chaff several parameters are needed which describe the chaff cloud and the signal it returns to the radar. Some of the needed parameters to describe the effectiveness of chaff clouds are: the chaff cloud size when fully developed, the time required for the full cloud to develop, the rate at which chaff bundles are dispensed, the number of bundles dispensed, and dipole response tables which describe the way in which the individual particles reflect the radar energy. The dynamics of the chaff clouds, both position relative to the aircraft and velocity profile of the clouds, are important and must be represented in the simulation. The relative position impacts the closest approach between target aircraft and missile, and the velocity profile identifies when a radar system can discriminate in Doppler.

Towed Decoy

The purpose of a towed decoy is to have the missile's trajectory altered so that the miss distance between target and missile is significantly increased. The decoy is deployed and towed behind the targeted aircraft. The decoy can either present a false target signal from skin return from the decoy itself, or a repeater on the decoy can amplify and return the radar signal from the illuminating radar presenting a strong return echo to the tracking radar receiver, or any of the deceptive techniques discussed in other ASPs can be used. What the tracker is presented with is two targets, the echo from the target aircraft and the signal from the decoy. When the decoy works as intended, the tracker will choose the decoy signal and guide on it pulling the missile away from the intended target.

To represent the decoy a number of decoy characteristics must be defined and modeled. These include: the time it takes to deploy the decoy, the rate of deployment behind the aircraft, the fully deployed position of the decoy with respect to the aircraft, the RCS of the decoy, and the characteristics of the signal repeated by the decoy.

2.9.1 Functional Element Design Requirements

This section contains the design requirements necessary to implement the off-board noise ECM simulation.

a. ESAMS will simulate the jamming signals introduced into target tracking radars, missile seekers, and missile fuzes by towed decoys.

   ESAMS will calculate the geometry of the towed decoy relative to the target aircraft. The radar return signal to the tracking radar, missile seeker, or fuze from the decoy skin return will be calculated, and the signal generated and returned to the tracking radar, missile seeker, or fuze by the towed decoy active jammer will be calculated. From these the complex voltages at the receivers' sum, azimuth difference and elevation difference channels will be calculated using standard radar equations. These values will be passed on to be used in the signal processing functional area in ESAMS.

b. ESAMS will simulate the jamming signals introduced into target acquisition, tracking, and missile seeker radars by chaff.

   ESAMS will calculate the geometry of the chaff relative to the target aircraft. The dynamics of the chaff cloud will be modeled including the deployment rate and geometry of the chaff bundles and the development of the chaff cloud over time. The characteristics of the radar signals returned over time from the chaff cloud will be developed based on the dispersion and RCS of the individual dipole scatterers. Both passive and active chaff will be simulated. For passive chaff the reflected signals from the threat radar are used to calculate the signal return, and active chaff uses the reflected signals from an on-board jammer to calculate the returned signals. Complex voltages at the threat receivers' sum, azimuth difference and elevation difference channels will be calculated using standard radar equations. These values will be passed on to be used in the signal processing functional area in ESAMS.

2.9.2 Functional Element Design Approach

This section describes the design approach (equations, algorithms, and methodology) implementing the design requirements of the previous section. The towed decoy can theoretically be used to generate any of the waveforms described in on-board jamming VSDRs for ESAMs (FEs 1.3.1.1 and 1.3.2.1). The generation of the specific waveforms is discussed in these sections, and will not be repeated here. This section will discuss only those added elements which are necessary to simulate the towed decoy. The main difference between on-board jamming and towed decoys is the distance that the jammer is removed from the targeted aircraft. The design elements needed to simulate that effect are determining the relative geometry of the towed decoy, calculating the radar return from the towed decoy skin, and then useing the range from the towed decoy to the jammed radar receiver in calculating the jamming signals (described in other VSDRs) into the victim radar.

To simulate chaff the geometry of the dispensed chaff bundle centroids, the geometry and dispersion of the chaff particles and dynamics of the cloud formation over time need to be calculated. Additionally the radar or jammer signal return from the chaff clouds needs to be calculated. These are included in the design elements below.

Design Element 9-1: Decoy Geometry

This portion of the design addresses the calculation of the relative geometry of the decoy with respect to the target aircraft, and converts the geometry to inertial coordinates to be used for radar power and voltage calculations.

To calculate the voltages introduced into the jammed radar receiver, the towed decoy orientation, position, and velocity must be known. The first of these—orientation—is obtained by knowing that the TD orientation is the same as the target aircraft orientation. The TD position is computed from the total deployed length, the angular position of the towed decoy in target body coordinates, and the target orientation.

The total deployed length in x, y, z coordinates behind the aircraft is given by the deployment rate times the time since deployment. This length is limited to the maximum deployment distance. The location of the towed decoy in target body coordinates is computed by.

$$\mathrm{DISOUT} = \mathrm{DPLRAT} \times \mathrm{TIMEDEP} \qquad [2.9\text{-}1]$$

Where DISOUT is the distance the decoy has deployed in the time since deployment started (TIMEDEP) at a deployment rate of DPLRAT. The maximum x, y, and z coordinates of the decoy relative to the target are ratioed based on the fraction of total deployment of the decoy. If the decoy is fully deployed the relative x, y, and z components are equal to the input maximum deployment components; TDXMAX, TDYMAX, and TDZMAX.

$$\mathrm{XOUT} = \mathrm{TDXMAX} \times \mathrm{DISOUT} / \mathrm{DISMAX} \qquad [2.9\text{-}2]$$

$$\mathrm{YOUT} = \mathrm{TDYMAX} \times \mathrm{DISOUT} / \mathrm{DISMAX} \qquad [2.9\text{-}3]$$

$$\mathrm{ZOUT} = \mathrm{TDZMAX} \times \mathrm{DISOUT} / \mathrm{DISMAX} \qquad [2.9\text{-}4]$$

The relative coordinates XOUT, YOUT, and ZOUT are transformed into inertial coordinates using the coordinate transfer routines described in other VSDRs, resulting in XOUTI, YOUTI, and ZOUTI respectively. The TD position in inertial coordinates is then given by

$$\mathrm{TDX} = \mathrm{XOUTI} + \mathrm{TGTX} \qquad [2.9\text{-}5]$$

$$\mathrm{TDY} = \mathrm{YOUTI} + \mathrm{TGTY} \qquad [2.9\text{-}6]$$

$$TDZ = ZOUTI + TGTZ \tag{2.9-7}$$

where TGTX, TGTY, and TGTZ are the target inertial coordinates.

The range from the TD to the jammed radar is calculated using the TD x, y, and z coordinates from above and the algorithms described in design element 4-1.

Finally, the TD velocity is determined in a similar fashion. If the TD is fully deployed, the velocity of the TD is the same as the aircraft. If the TD is in the process of deploying, then the returned velocity includes the deployment velocity. The deployment rate in target body coordinate system x, y, and z components is calculated by projecting the total deployment rate into the deployment direction vector.

$$DPLXD = DPLRAT \times TDXMAX / DISMAX \tag{2.9-8}$$

$$DPLYD = DPLRAT \times TDYMAX / DISMAX \tag{2.9-9}$$

$$DPLZD = DPLRAT \times TDZMAX / DISMAX \tag{2.9-10}$$

Here DPLXD, DPLYD, and DPLZD are the towed decoy deployment velocity components in target in target body coordinates, DPLRAT is the towed decoy deployment rate, TDXMAX, TDYMAX, and TDZMAX are the maximum deployment x, y, and z values in target body coordinates, and DISMAX is the maximum deployment distance.

DPLXD, DPLYD, and DPLZD are transformed to inertial coordinate components (XD, YD, and ZD) using algorithms described in other VSDRs. The deployment velocity is then added to the target velocity to get TD velocity.

$$TDXDOT = AVX + XD \tag{2.9-11}$$

$$TDYDOT = AVY + YD \tag{2.9-12}$$

$$TDZDOT = AVZ + ZD \tag{2.9-13}$$

AVX, AVY, and AVZ are the aircraft's x, y, and z velocity components, and TDXDOT, TDYDOT, and TDZDOT are the TD x, y, and z velocity components.

These position components are then used to calculate towed decoy ranges to targets as described in FE 1.3.1.1 and along with the velocity components are used in calculating signal power, Doppler, phase and voltages returned to the receiver as described in FE 1.3.1.1.

Design Element 9-2: Towed Decoy Skin Return

The skin return from the towed decoy is calculated using the same standard radar signal propagation equations used elsewhere in ESAMs and documented in Section 2.5. The skin return code computes a voltage coefficient given by

$$\mathrm{VCOEF} = \frac{\sqrt{\dfrac{\mathrm{PWRTX} \times \mathrm{WVLTX}^2}{\mathrm{FPI3} \times \mathrm{RSTD}^2 \times \mathrm{RVTD}^2}}}{\mathrm{XLOSS}} \qquad [2.9\text{-}14]$$

PWRTX is the transmitter power, WVLTX is the transmitter wavelength, FPI3 is four pi cubed, RSTD is the range from the towed decoy to the transmitter, RVTD is the range from the towed decoy to the receiver, and XLOSS is the receiver loss factor. The towed decoy RCS is included in the calculation by multiplying its square root by the above factor. Thus the voltage coefficient is calculated,

$$\mathrm{VCOEFS} = \mathrm{VCOEF} \times \sqrt{\mathrm{TDRCS}} \qquad [2.9\text{-}15]$$

When TDRCS is the towed decoy radar cross section drawn from RCS table inputs for the towed decoy for the angle of towed decoy being looked at, as determined by a call to the towed decoy RCS routine TDRCS. The angle of view on the towed decoy is determined using the standard geometry equations detailed in other VSDRs.

The voltage coefficient is used in conjunction with the antenna gain pattern data and signal phase delay to compute the induced voltages. The signal phase is computed from the transmitter and receiver ranges

$$\mathrm{PHAZ} = \mathrm{PIX2} / \mathrm{WVL} \times \mathrm{MOD}(\mathrm{RSTD} + \mathrm{RVTD}, \mathrm{WVL}) \qquad [2.9\text{-}16]$$

Here PHAZ is the phase, PIX2 is two times pi, RSTD is the range from transmitter to towed decoy, RVTD is the range from receiver to towed decoy, and WVL is the wavelength of the signal being computed. For acquisition and tracker radars, WVL is the ground tracking radar wavelength. For seeker calculations, it is the illuminator wavelength, and for fuze calculations, it is the fuze wavelength. The cosine and sine of the phase delay give the real and imaginary components of the complex number for the phase, PHDEL. The complex for phase delay is documented in FE 1.3.1.1.

$$\mathrm{PHDEL} = \cos(\mathrm{PHAZ}) + i\sin(\mathrm{PAHZ}) = e^{i\mathrm{PHAZ}} \qquad [2.9\text{-}17]$$

The voltage coefficient, phase, and antenna pattern data provide the information to compute the induced voltages in the three radar channels. These are given by

$$\mathrm{SUMJAM} = \mathrm{VCOEFS} \times \mathrm{GILL} \times \mathrm{GRCVR} \times \mathrm{PHDEL} \qquad [2.9\text{-}18]$$

$$\mathrm{DFJMAZ} = \mathrm{VCOEFS} \times \mathrm{GILL} \times \mathrm{GDFAZ} \times \mathrm{PHDEL} \qquad [2.9\text{-}19]$$

$$\mathrm{DFJMEL} = \mathrm{VCOEFS} \times \mathrm{GILL} \times \mathrm{GDFEL} \times \mathrm{PHDEL} \qquad [2.9\text{-}20]$$

In these equations, GILL is the transmitter antenna voltage gain, GRCVR is the receiver sum channel voltage gain, GDFAZ is the receiver azimuth difference channel voltage gain, GDFEL is the receiver elevation difference channel voltage gain, SUMJAM is the voltage induced in the receiver sum channel by the towed decoy, and DFMEL is the voltage induced in the elevation channel by the towed decoy.

Several additional values are computed to provide a complete description of the towed decoy voltage at the receiver. These include the Doppler shift, the pulse width, and the apparent range. The first of these—Doppler shift—is dependent on closing velocity:

$$\begin{aligned}VCL = &((TDXDOT \times XSTD) + (TDYDOT \times YSTD) + (TDZDOT \times ZSTD))\\ &/RSTD + (((TDXDOT - XVDOT) \times XVTD) + ((TDYDOT - YVDOT)\\ &\times YVTD) + ((TDZDOT - ZVDOT) \times ZVTD))/RVTD\end{aligned} \quad [2.9\text{-}21]$$

In the above, XSTD, VSTD, and ZSTD are the towed decoy to transmitter separation components in x, y, and z; XVDOT, YVDOT, and ZVDOT are the receiver velocity components in x, y, and z; XVTD, YVTD, and ZVTD are the decoy to transmitter range; and RVTD is the towed decoy to receiver range. These are calculated using algorithms described in the section on FE 1.3.1.1. VCL is the two way range rate.

The above equation assumes that the transmitter is not moving. The associated Doppler shift is computed from the range rate and the wavelength as (see FE 1.3.1.1)

$$DOPJAM = -VCL/WVL \quad [2.9\text{-}22]$$

In this calculation, DOPJAM is the Doppler shift of the towed decoy as sensed by the receiver, VCL is the two way closing velocity computed above, and WVL is the transmitter wavelength. The minus sign accounts for the fact that a positive range rate gives a negative Doppler shift and vice versa.

The pulse width and apparent range associated with the towed decoy skin return are set equal to the transmitter pulse width and the transmitter to towed decoy range.

Design Element 9-3: Jammer Complex Waveforms at Radar

The complex waveforms at the jammed radar receiver are calculated using the same equations described for jamming in FEs 1.3.1.1 and 1.3.2.1, On Board Noise and On Board Deceptive ECM respectively. The difference is that for towed decoys the range from the towed decoy to the radar transmitter and receiver is used to calculate the signals instead of the range to the jamming aircraft as in the case for on-board jamming. The calculation of the complex wave forms is not repeated here.

Design Element 9-4: Geometry of Chaff Bundles

The chaff model in ESAMS 2.7 develops scatterers of radar energy in a chaff cloud. The chaff is either passive or active (see figure 2.9-1). For passive chaff, the threat radar illuminates the chaff (R5), and the degradation is due to the reflection of this energy (returned to the ground receiver, R5 or to the missile R3). For active chaff, an on-board jammer illuminates the chaff cloud (R2), and it is this illuminating source that induces degradation in the victim radar (R4 and R3).

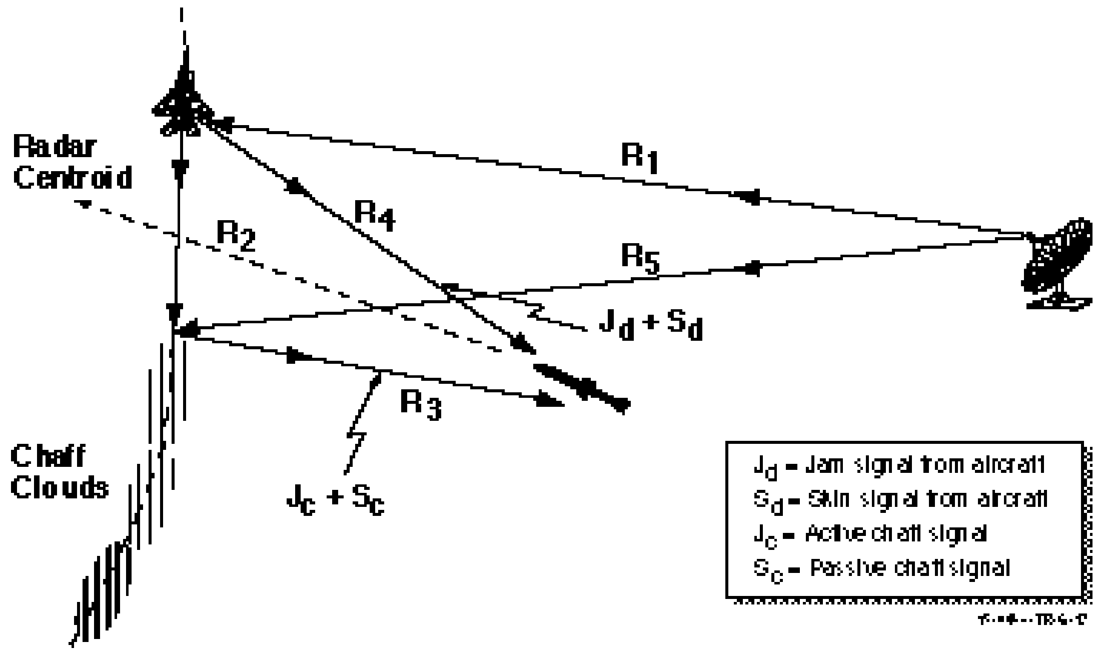


FIGURE 2.9-1. Engagement Geometry Including Chaff.

To calculate the signal returns to the jammed radar the position of the chaff clouds and the movement and development of the clouds with time must be calculated. This design element describes the calculation of the chaff bundle geometry including the movement of the cloud due to aircraft speed at dispense, deceleration of the cloud particles and blooming of the cloud particles to maximum size over time.

The model develops spatial location and size of the chaff cloud according to the input schedule of chaff dispersal, the characteristic parameters of the chaff, and the time in the engagement when the effect of chaff is desired. The radar energy scattering properties are computed at that time. The chaff clouds are scheduled to be dispersed in one or more parcels (corresponding to chaff cartridges) in a dispense event. A dispense event is characterized by the number of parcels to be dispensed, the initial times of dispense for each parcel in the event, and the characteristic growth and scattering properties of each parcel. In order to simulate some stochastic behavior of the chaff parcel dispersal, each parcel is nationally subdivided into five equal subparcels which are called scatterers. The locations of the centers of these subparcels are shifted from the nominal mean location of the parent parcel by random processes. The development of the equations below is documented in [34].

The dispense of the n-th parcel in a cloud is marked by the time that the parcel dispense beings, t_{in}. The chaff cloud growth is characterized by the following parameters:

$\bar{v}_{fall}$ = mean fall speed of chaff dipoles

σ_{vl} = standard deviation of chaff scatterer velocity in the longitudinal direction

σ_{vr} = standard deviation of chaff scatterer velocity in the radial direction

τ_d	=	time constant for chaff cloud growth in the radial (lateral) direction
τ_{vl}	=	time constant for random contribution to scatterer longitudinal velocity
τ_{vr}	=	time constant for random contribution to scatterer radial velocity
D_{sep}	=	separation distance from dispensing target where chaff starts to disperse
a_{decel}	=	constant deceleration of chaff in longitudinal direction
D_{max}	=	characteristic diameter of scatterers in the parcel at time τ_d after dispensing of chaff.

These parameters have specific values embedded in the ESAMS code (subroutine CHAFFI).

The positioning in space of the scatterers (subparcels) in the n-th dispensed parcel is first determined in a body-oriented coordinate system related to the dispensing target aircraft at the initial time of chaff cloud dispense: x* corresponds to a “horizontal” lateral direction (right wing), y* corresponds to the longitudinal axis of the aircraft (nose), and z* corresponds to a “vertical” lateral direction (top). The centers of the five subparcels (j=1,2,3,4,5) are located in terms of time-evolution factors and gaussian random number (of zero mean and unit standard deviation) u_g. The time-evolution factors for the n-th parcel are:

$$F_{3n}(t) = \frac{\sigma_{vr} \times \tau_{vr}}{\sqrt{2}} \times (1 - e^{-(t - t_{in})/\tau_{vr}}) \qquad [2.9\text{-}23]$$

$$F_{4n}(t) = \frac{1}{2} D_{max} \times (1 - e^{-(t - t_{in})/\tau_d}) \qquad [2.9\text{-}24]$$

$$F_{5n}(t) = \sigma_{vl} \tau_{vl} (1 - e^{-(t - t_{in})/\tau_{vl}}) \qquad [2.9\text{-}25]$$

With these factors and gaussian random numbers generated for each direction, each parcel and each subparcel $(u_{Gjnx}\ \text{etc.})$, the lateral position components of the subparcels are given by

$$\begin{aligned} x_{jn}(t) &= u_{Gjnx} \times F_{3n}(t), && j = 1, 2, 4 \\ &= u_{Gjnx} \times F_{3n}(t) \pm F_{4n}(t) && j = 3(+), 5(-) \end{aligned} \qquad [2.9\text{-}26]$$

$$\begin{aligned} z_{jn}(t) &= u_{Gjnx} \times F_{3n}(t), && j = 1, 2, 4 \\ &= u_{Gjnx} \times F_{3n}(t) \pm F_{4n}(t) && j = 3(+), 5(-) \end{aligned} \qquad [2.9\text{-}27]$$

The growth of the cloud in lateral directions is simulated by the non-random lateral displacements generated by the F_{4n} shifts of scatterers 3 and 5.

The longitudinal position component takes account of the slowing of the chaff from the speed of the dispensing aircraft to zero speed relative to the air mass. This is modeled by a constant deceleration according to the deterministic equation:

$$y_{jnd}(t) = -D_{sep} + v_{Ti} \times (t - t_I) - \frac{1}{2} a_{decel} \times (t - t_I)^2 \qquad [2.9\text{-}28a]$$

This holds for times before the scatterer comes to rest in the air mass. When the scatterer has come to rest,

$$y_{jnd}(t) = -D_{sep} + v_{Ti} \times (t_{in} - t_I) + \frac{1}{2} v_{Ti}^2 / a_{decel} \ . \qquad [2.9\text{-}28b]$$

Here, v_{Ti} is the speed of the dispensing aircraft at dispense, t_I is the start of the dispense event, and t_{in} (as before) is the start of dispense of the nth parcel in the event. Then, the final y*-position of the scatterers is obtained by including some randomization:

$$y_{jn}(t) = y_{jnd}(t) + u_{gjny} \times F_5(t) \qquad [2.9\text{-}29]$$

The velocity components of the scatterers (in the x*, y*, z* coordinates) are obtained in a similar way. These velocities relax to zero, but with randomness modeled. The relaxation is incorporated with the factors:

$$C_{v1n}(t) = \frac{\sigma_{vr}}{\sqrt{2}} \times e^{-(t - t_{in}) / \tau_{vr}} \qquad [2.9\text{-}30]$$

$$C_{v2n}(t) = \frac{1}{2} \times \frac{D_{max}}{\tau_d} e^{-(t - t_{in}) / \tau_d} \qquad [2.9\text{-}31]$$

$$C_{v3n}(t) = \sigma_{vl} e^{-(t - t_{in}) / \tau_{vl}} \qquad [2.9\text{-}32]$$

Then the lateral components of velocity for the scatterers are given by

$$\begin{aligned} v_{xjn} &= u_{Gjnx} \times C_{v1n}(t) & j &= 1, 2, 4 \\ &= u_{Gjnx} \times C_{v1n}(t) \pm C_{v2n}(t) & j &= 3(+), 5(-) \end{aligned} \qquad [2.9\text{-}33]$$

$$\begin{aligned} v_{zjn} &= u_{Gjnz} \times C_{v1n}(t) & j &= 1, 2, 4 \\ &= u_{Gjnz} \times C_{v1n}(t) \pm C_{v2n}(t) & j &= 3(+), 5(-) \end{aligned} \qquad [2.9\text{-}34]$$

The longitudinal velocity component takes account of the slowing of the chaff to rest in the air mass, using the constant deceleration model. Until the chaff has come to rest, the deterministic equations are

$$v_{yjnd}(t) = v_{Ti} - a_{decel} \times (t - t_{in}) \quad [2.9\text{-}35a]$$

and after coming to rest:

$$v_{yjnd}(t) = 0 . \quad [2.9\text{-}35b]$$

Then the randomized components of the parcels are

$$v_{yjn}(t) = v_{yjnd}(t) + u_{Gjnz} \; C_{v3n}(t) \quad [2.9\text{-}36]$$

After the scatterer positions and velocities have been computed as above, they are then transformed into the inertial reference coordinates, which includes a translation to the inertial position of the dispensing aircraft at the start of the event, and the effect of wind velocity in the inertial frame.

$$\vec{R}_{sjn} = \mathbf{U}\overrightarrow{R}_{jn} + \vec{R}_{Ti} + (\vec{V}_{wind} - \vec{V}_{fall}) \times (t - t_{in}) \quad [2.9\text{-}37]$$

$$\vec{V}_{sjn} = \mathbf{U}\overrightarrow{V}_{jn} + \vec{V}_{wind} - \vec{V}_{fall} \quad [2.9\text{-}38]$$

Here **U** is the rotational transformation from the starred coordinates fixed in target frame of reference to the inertial frame, $\vec{R}_{Ti}$ is the position of the dispensing aircraft at the start of the dispense event, and $\vec{V}_{wind}$ is the wind velocity. (The wind velocity used here is presently set to zero in subroutine CHAFFI; it is not the environmental wind velocity which can be entered in the ESAMS input.)

Design Element 9-5: Radar Return from Chaff

The next subelement of chaff impact is the determination of radar energy scattering properties of the chaff cloud scatterers. The development of the equations detailed below is documented in [34]. The chaff RCS “blooms” with a characteristic time constant τ_{RCS}. This quantity can be input as a single parameter for all radar wave-lengths, or it can be input as a table over several wavelengths (to be accessed by table lookup for the particular wavelength of interest.

Another scatterer characteristic is that of the maximum RCS for each parcel, σ_{RCSmax}. This quantity can be input as a table over several wavelengths for a specific chaff bundle type. Or it can be computed from a model of the chaff bundle in terms of the number N_i of elemental dipoles of length l_i, and cross section radius a_i, which yields an effective RCS per dipole of type i as σ_i. Then the maximum RCS for each scatterer is

$$\sigma_{RCSmax} = \sum_i N_i \sigma_i \quad [2.9\text{-}39]$$

If the wavelength λ is long compared to πl_i, the σ_i is computed by the off resonance formula (which includes averaging over all dipole orientations):

$$\sigma_i = \lambda^2 \times k^6 / \left(45\pi\left(\ln\left(2\frac{l_i}{a_i}\right) - 1\right)^2\right), \qquad [2.9\text{-}40]$$

where $k = 2\pi/\lambda$. For $\lambda < \pi l_i$, we are in the resonance regime, where the formula for σ_i is a very complicated formula best broken down into intermediate factors as follows:

$$\sigma_i = \lambda^2\left(\frac{3}{16\pi}\right)(A_1 + A_2 + A_3 + A_4 + A_5 + A_6) \qquad [2.9\text{-}41]$$

where

$$A_1 = (F_p^2 + F_{pp}^2)(2\pi k l_i/2 - 1) \qquad [2.9\text{-}42]$$

$$A_2 = (G_p^2 + G_{pp}^2)(2\pi k l_i/2 - 1 + \gamma_e + \ln(4 k l_i/2)$$

$$+ (\pi + 4kl_i/2)) \times \sin(2kl_i/2) \qquad [2.9\text{-}43]$$

$$+ \left(\frac{1}{2} - \frac{1}{5}\gamma_e - 2\ln(4kl_i/2)\right) \times \cos(2kl_i/2)$$

$$- \ln(2) \times \cos(4kl_i/2))$$

$$A_3 = (H_p^2 + H_{pp}^2)\left(2\pi\left(\frac{kl_i}{2}\right) - 1 + \gamma_e + \ln\left(4\left(\frac{kl_i}{2}\right)\right) - \left(\pi + 4\left(\frac{kl_i}{2}\right)\ln(2)\right)\right) \qquad [2.9\text{-}44]$$

$$A_4 = (G_p H_p + G_{pp} H_{pp}) \times \left(3\left(\frac{kl_i}{2}\right)\ln(2)\cos\left(2\left(\frac{kl_i}{2}\right)\right) - \sin\left(2\left(\frac{kl_i}{2}\right)\right)\right) \qquad [2.9\text{-}45]$$

$$A_5 = (F_p G_p + F_{pp} G_{pp}) \times \left(\pi + \sin\left(\frac{kl_i}{2}\right)\right.$$

$$\left. - 2\left(\gamma_e + \ln\left(4\left(\frac{kl_i}{2}\right)\right)\cos\left(\frac{kl_i}{2}\right) - 2\ln(2)\cos\left(3\left(\frac{kl_i}{2}\right)\right)\right)\right) \qquad [2.9\text{-}46]$$

$$A_6 = (F_p H_p + F_{pp} H_{pp}) \times \left(\pi\cos\left(\frac{kl_i}{2}\right) - 2 \times \left(\gamma_e + \ln\left(4\left(\frac{kl_i}{2}\right)\right)\right) \times \sin\left(\frac{kl_i}{2}\right)\right.$$

$$\left. + 2\ln(2)\sin\left(3\left(\frac{kl_i}{2}\right)\right)\right) . \qquad [2.9\text{-}47]$$

Here γ_e is the Euler constant (0.5772156649). The intermediate factors F, G, and H are given by:

$$F_p = X_\omega / (\pi^2 + X_\omega^2) \qquad [2.9\text{-}48]$$

$$F_{pp} = \pi / (\pi^2 + X_\omega^2) \qquad [2.9\text{-}49]$$

where

$$X_\omega = -2\left(\gamma_e + \ln\left(\frac{ka_i}{2}\right)\right); \qquad [2.9\text{-}50]$$

$$G_{pp} = \frac{1}{2}\chi_1 / (\psi_1^2 + \chi_1^2) \qquad [2.9\text{-}51]$$

$$G_p = \frac{1}{2}\psi_1 / (\psi_1^2 + \chi_1^2) - \pi G_{pp} / (2X_\omega) \qquad [2.9\text{-}52]$$

where

$$\psi_1 = \frac{\pi}{4}\sin\left(\frac{kl_i}{2}\right) + \left(1 - \frac{1}{2}\gamma_e - \frac{1}{2}\ln\left(\frac{kl_i}{2}\right) - X_\omega\right)\cos\left(\frac{kl_i}{2}\right) \qquad [2.9\text{-}53]$$

$$\chi_1 = \frac{1}{2}\left(\gamma_e + \ln\left(4\left(\frac{kl_i}{2}\right)\right)\right)\sin\left(\frac{kl_i}{2}\right) - \frac{\pi}{4}\cos\left(\frac{kl_i}{2}\right); \qquad [2.9\text{-}54]$$

$$H_{pp} = \frac{1}{2}\chi_2(\psi_2^2 + \chi_2^2) \qquad [2.9\text{-}55]$$

$$H_p = \frac{1}{2}\psi_2(\psi_2^2 + \chi_2^2) - \pi H_{pp} / (2X_\omega) \qquad [2.9\text{-}56]$$

where

$$\psi_2 = \frac{\pi}{4}\sin\left(\frac{kl_i}{2} - \frac{\pi}{2}\right) + \left(1 - \frac{1}{2}\gamma_e - \frac{1}{2}\ln\left(\frac{kl_i}{2}\right) - X_\omega\right)\cos\left(\frac{kl_i}{2} - \frac{\pi}{2}\right) \qquad [2.9\text{-}57]$$

$$\chi_2 = \frac{1}{2}\left(\gamma_e + \ln\left(4\left(\frac{kl_i}{2}\right)\right)\right)\sin\left(\frac{kl_i}{2} - \frac{\pi}{2}\right) - \frac{\pi}{4}\cos\left(\frac{kl_i}{2} - \frac{\pi}{2}\right) \qquad [2.9\text{-}58]$$

a_i is the dipole cross-sectional radius.

The total σ_{RCSmax} is divided by 5 to get the value appropriate to each of the five subparcels, the chaff cloud scatterers.

When the mean spacing between the individual dipoles is several times the wavelength of the illuminating radar, the RCS of a dispersed chaff parcel is the σ_{RCSmax} determined from equation [2.9-39] and following equations. However, when the chaff cloud is more dense than this limit, the RCS of the cloud is more and more related to the projected area of the cloud and less related to the RCS of individual chaff dipoles. Consequently, the size of the cloud is important, since that is inversely related to the mean spacing between dipoles. The size of the cloud is determined from the dispersion of the subparcels for all the parcels presently in the cloud. In the inertial coordinate system, the x, y, and z extremes of the cloud are determined as follows:

$$X_{min} = \text{minimum of}\{X_{sjn}\} \tag{2.9-59}$$

$$X_{max} = \text{maximum of}\{X_{sjn}\} \tag{2.9-60}$$

$$Y_{min} = \text{minimum of}\{Y_{sjn}\} \tag{2.9-61}$$

$$Y_{max} = \text{maximum of}\{Y_{sjn}\} \tag{2.9-62}$$

$$Z_{max} = \text{maximum of}\{Z_{sjn}\} \tag{2.9-63}$$

$$Z_{min} = \text{minimum of}\{Z_{sjn}\} \tag{2.9-64}$$

where X_{sjn}, Y_{sjn}, and Z_{sjn} are the x-, y-, and z-components of $\vec{R}_{sjn}$ from equation [2.9-37], n ranges over the parcels in the cloud, and j ranges over the subparcels in each parcel.

The unit vector along the cloud heading (horizontal) is now found by the components:

$$\begin{aligned} X_{hdg} &= (X_{max} - X_{min}) / [(X_{max} - X_{min})^2 + (Y_{max} - Y_{min})^2]^{1/2} \\ Y_{hdg} &= (Y_{max} - Y_{min}) / [(X_{max} - X_{min})^2 + (Y_{max} - Y_{min})^2]^{1/2} \end{aligned} \tag{2.9-65}$$

The center point of the cloud is at the point having the coordinates:

$$\begin{aligned} X_{ctr} &= (X_{max} + X_{min}) / 2 \\ Y_{ctr} &= (Y_{max} + Y_{min}) / 2 \\ Z_{ctr} &= (Z_{max} + Z_{min}) / 2 \end{aligned} \tag{2.9-66}$$

(It is assumed that there has been negligible vertical maneuvering of the dispensing aircraft during the dispense event, so there is no z-component for the cloud heading.)

The cloud is now modeled as a rectangular parallelepiped with a length along the heading direction (specified by X_{hdg} and Y_{hdg}), a horizontal width given as twice the average displacement of the subparcel scatterers from the heading direction, and a vertical extent given by $(Z_{max} - Z_{min}) / \sqrt{2}$. This approximation facilitates the computation of projected area of the cloud from the viewpoints of both the RF transmitter and the RF receiver involved. The length of the cloud is given by

$$L_{cloud} = [(X_{max} - X_{min})^2 + (Y_{max} - Y_{min})^2]^{1/2} . \qquad [2.9\text{-}67]$$

Let the horizontal vector from (X_{min}, Y_{min}) to the center of the jn-th scatterer (j-th subparcel in n-th parcel) be $\vec{R}_{jno}$ and let the unit vector along the heading be $\vec{R}_{hdg}$. Then the magnitude of the displacement of the jn-th scatterer from the heading is

$$D_{jn} = \left| \vec{R}_{jno} - \vec{R}_{hdg} \times (\vec{R}_{hdg} \cdot \vec{R}_{jno}) \right| \qquad [2.9\text{-}68]$$

Then, if N_{scat} is the number of scatterers in the cloud, the cloud width is

$$W_{cloud} = 2 \times \left(\sum_{jn} D_{jn} \right) \Big/ N_{scat} . \qquad [2.9\text{-}69]$$

The factor of two arises because we want the cloud to extend equally on either side of the heading. The height of the cloud is

$$H_{cloud} = (Z_{max} - Z_{min}) \sqrt{2} \qquad [2.9\text{-}70]$$

where the $\sqrt{2}$ divisor represents an estimation of root-mean square for vertical extent.

The cloud is now represented by rectangular faces on the top and bottom, on the two sides parallel to the heading, and on the two sides perpendicular to the heading; the areas of these faces are, respectively,

$$\begin{aligned} A_{top} &= L_{cloud} \times W_{cloud} \\ A_{side} &= L_{cloud} \times H_{cloud} \\ A_{end} &= W_{cloud} \times H_{cloud} \end{aligned} \qquad [2.9\text{-}71]$$

When the cloud is viewed along a direction described by a unit vector $\vec{U}$, the cloud presents an area to the viewer given by

$$A_{proj} = \vec{U} \cdot \vec{n}_{top} A_{top} + \vec{U} \cdot \vec{n}_{side} A_{side} + \vec{U} \cdot \vec{n}_{end} A_{end} \qquad [2.9\text{-}72]$$

where the unit vectors $\vec{n}$ are normal to the indicated faces with senses chosen to have a positive (or zero) projection along $\vec{U}$.

In many cases of interest, there are two viewers of interest: the transmitter of RF energy illuminating chaff (e.g., the ground radar illuminator or the aircraft itself) and the receiver of RF energy scattered from the chaff (e.g., the missile seeker or a ground tracker). The effective bistatic projected area of the chaff cloud is thus taken to be the arithmetic mean of the areas seen from the two viewers:

$$A_{proj}^{bistatic} = (A_{proj}^{xmit} + A_{proj}^{revr})/2 \qquad [2.9\text{-}73]$$

As mentioned above, when the chaff dipoles are far apart they scatter independently so the cloud RCS is just that of the RCS of a single dipole times the number of dipoles in the cloud, while when the cloud is densely packed, the cloud RCS is just the bistatic projected area of the cloud presented to the viewers. The total RCS of a cloud is interpolated between these two extremes by the following formula [35]:

$$\sigma_{cloud} = A_{proj}^{bistatic} \times (1 - e^{-n\sigma_1}) \qquad [2.9\text{-}74]$$

where the number of dipoles per projected area is

$$n = N / A_{proj}^{bistatic} \qquad [2.9\text{-}75]$$

and σ_1 is the spatially averaged RCS of a single dipole (say, as computed by equation [2.9-41]). This formula is extended to our case of more than one type of dipole present by taking the $N\sigma_1$ for equations [2.9-74 and -75] combined and replacing it as follows:

$$N\sigma_1 = \sigma_{RCSTot} \times 5 \times N_{parc} \qquad [2.9\text{-}76]$$

where σ_{RCSTot} is the total RCS computed earlier for a single subparcel, 5 is the number of subparcels per parcel, and N_{parc} is the number of parcels in the current cloud.

Finally, all the preceding elements are put together using standard signal voltage calculations to obtain the receiver front end voltage due to chaff in channel L (L=sum, azimuth difference, or elevation difference) as follows:

$$V_L = \frac{\sqrt{\dfrac{(P_{TX} G_T \lambda^2 \sigma_{cloud} F_{RCS}(t))}{(4\pi)^3 R_{TC}^2 R_{RC}^2}}}{X_{loss}} \times G_{RL} e^{2\pi i(\mathrm{mod}(R_{TC} + R_{RC}))/\lambda} \qquad [2.9\text{-}77]$$

where

G_T	=	transmitter antenna gain toward chaff cloud
G_{RL}	=	receiver antenna voltage gain for channel L toward cloud (L=sum, azimuth difference, or elevation difference)
R_{TC}	=	distance from transmitter to chaff cloud
R_{RC}	=	distance from receiver to chaff cloud
P_{TX}	=	transmitter (peak) power
λ	=	transmitter wavelength
X_{loss}	=	receiver loss factor
σ_{cloud}	=	chaff cloud bistatic RCS

and

$$F_{RCS}(t) = 1 - \exp(-(t - t_{in})/\tau_{RCS}) \qquad [2.9\text{-}78]$$

where

τ_{RCS} = time constant for chaff bloom effect.

The Doppler shift associated with these signals is given as (see FE 1.3.1.1)

$$f_{dop} = (v_{xcl} + v_{Rcl})/\lambda \qquad [2.9\text{-}79]$$

where

v_{xcl} = closing velocity of transmitter on chaff cloud
v_{Rcl} = closing velocity of receiver on chaff cloud

2.9.3 Functional Element Software Design

This section describes the software design necessary to implement the functional element requirements for deceptive off-board ECM, as outlined in Section 2.9.1 and the design approach as outlined in Section 2.9.2. Section 2.9.3 is organized as follows. This first section has four subparts: The first part describes the overall subroutine hierarchy and gives capsule descriptions of the relevant subroutines; the second part contains logical flow charts for the functional element as a whole, and describes the major operations represented by each block in the charts; the third part presents detailed logical flow charts for the subroutines; and the last part contains a description of all input and output for the functional element as a whole and for each subroutine that implements the functional element.

ECM Deceptive Off-Board Subroutine Hierarchy

The Fortran call tree implemented for the ECM Deceptive Off-Board Functional Element in the ESAMS 2.7 computer code is shown in Figure 2.9-2. The diagram depicts the entire model structure from the top level ZINGER (the Main subprogram) through all the routines allocated to the functional element. Subroutines allocated directly to the implementation of the functional element are shaded. Subroutines which use functional element results are shown with a heavy-line box. The subroutines allocated to the functional element are listed in Table 2.9-1, together with brief descriptions of them.

The call tree for the off-board deceptive ECM structure shows that SKRCPI interfaces ECM with the missile seeker through a call to the ECM executive routine BEMGRM. WFTCPI and TWSEXC provide the same functions for the waveform driven ground tracker (two and three channel monopulse) and the track-while-scan ground radar respectively. Not shown here is the ground radar acquisition routine WFAPD. This routine would interface noise jamming against the acquisition mode of the waveform driven ground radars, and the towed decoy (TD) could be used to jam the acquisition mode. The noise jamming is thoroughly discussed in Section 2.5. Finally, the route through ENDER would determine if the missile would detonate on the chaff.

The TD code is well compartmentalized in ESAMS 2.7. Except for the initialization routine TDINI under ECMINI, the TD subroutines are all under the executive routine TDEXC. The subroutine TDDPLY provides data on TD deployment status, while TDPOS, TDVEL, and TDROL provide position, velocity, and orientation data. The TD skin signature impacting victim radar performance is developed by SKNSIG. Based on the flag FZONTD in the TD ECMD file, the missile may be allowed to fuze on the TD.

Four chaff routines interface the chaff code with the rest of ESAMS: CHFEXC, ILLCHF, CHFSIG, and CHFFUZ. CHFEXC provides initialization code, while CHFFUZ determines if the missile will detonate on chaff returns. The majority of the chaff development takes place through the subroutines ILLCHF and CHFSIG. ILLCHF develops the signature for illuminated chaff, while CHFSIG determines the signature for the passive case. The only difference is that the antenna jammer gain is used rather than the victim radar antenna gain for the illuminating signal in the ILLCHF methodology.

As discussed in the VSDRs for on-board noise and on-board deceptive ECM, there are a number of subroutines—called by BEMGRM—that develop the noise and deceptive ECM impact on the victim radar. They are the following: BEMEXC, BEMOUT, BEMSEN, BEMSVL, BEMTVL, BEMFVL, BEMANT, and BEMNZ. Both noise ECM (bin masking, continuous noise, swept spot noise) and deceptive on-board ECM (amplitude modulated, terrain bounce, crosseye, gate stealing) can be employed on the TD. Therefore, these subroutines are shown in Figure 2.9-2. However, since they are discussed elsewhere in detail, they are only covered peripherally in this document.

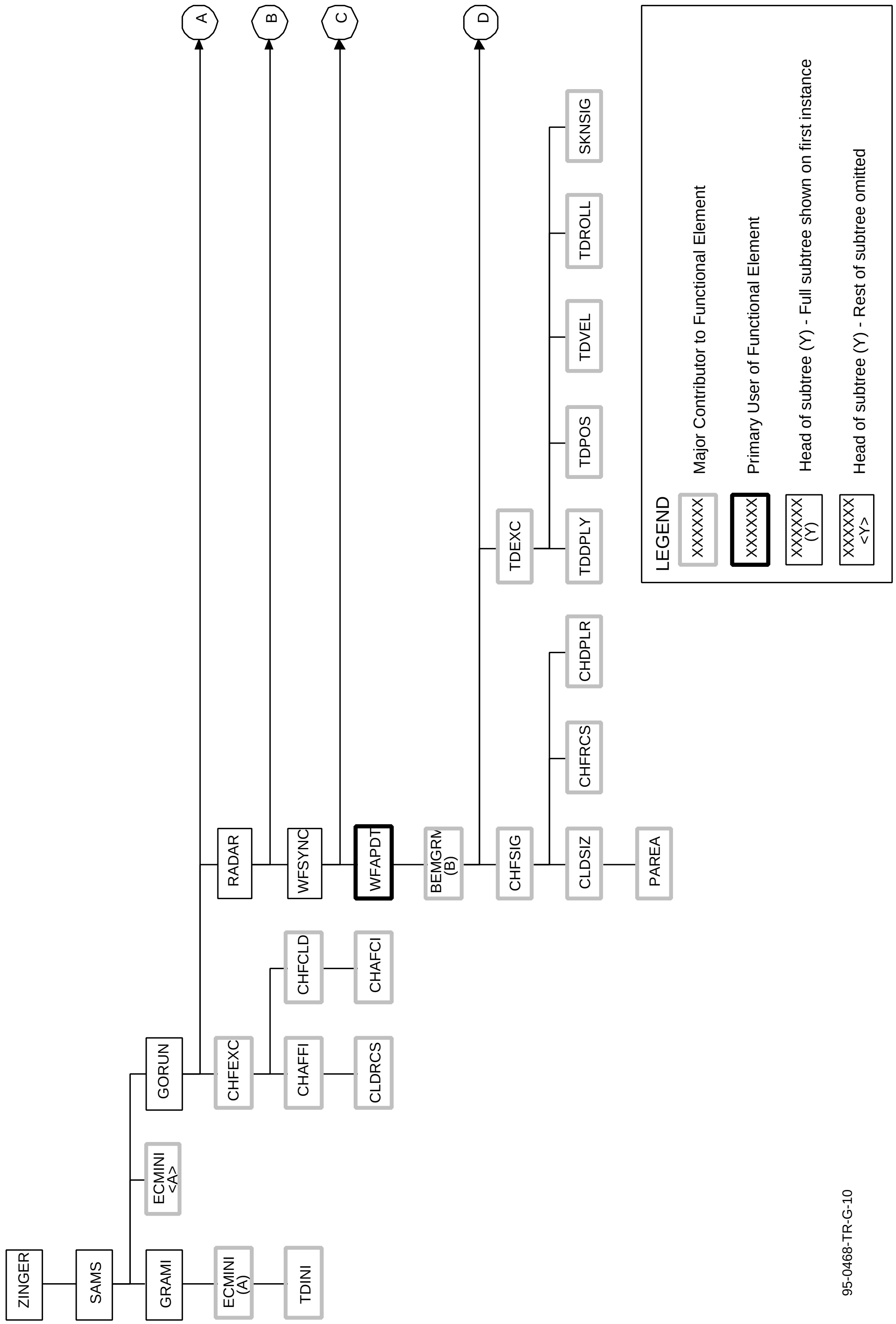
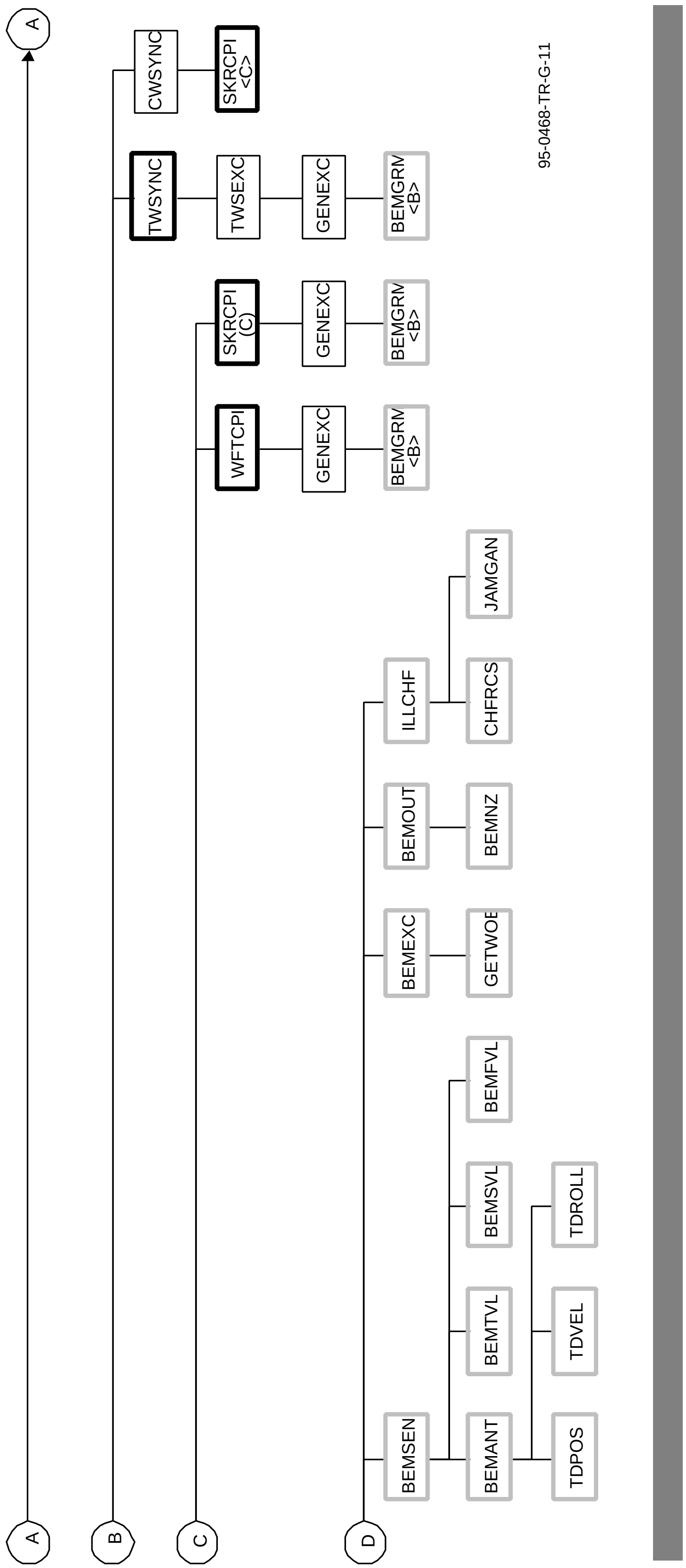


FIGURE 2.9-2. Deceptive Off-Board ECM.


A
CWSYNC
SKRCPI <C>
TWSYNC
TWSEXC
GENEXC
BEMGRM <B>
SKRCPI (C)
GENEXC
BEMGRM <B>
WFTCPI
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BEMGRM <B>
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JAMGAN
ILLCHF
CHFRCS
BEMOUT
BEMNZ
BEMEXC
GETWOE
BEMFVL
BEMSVL
TDROLL
BEMTVL
TDVEL
BEMSEN
BEMANT
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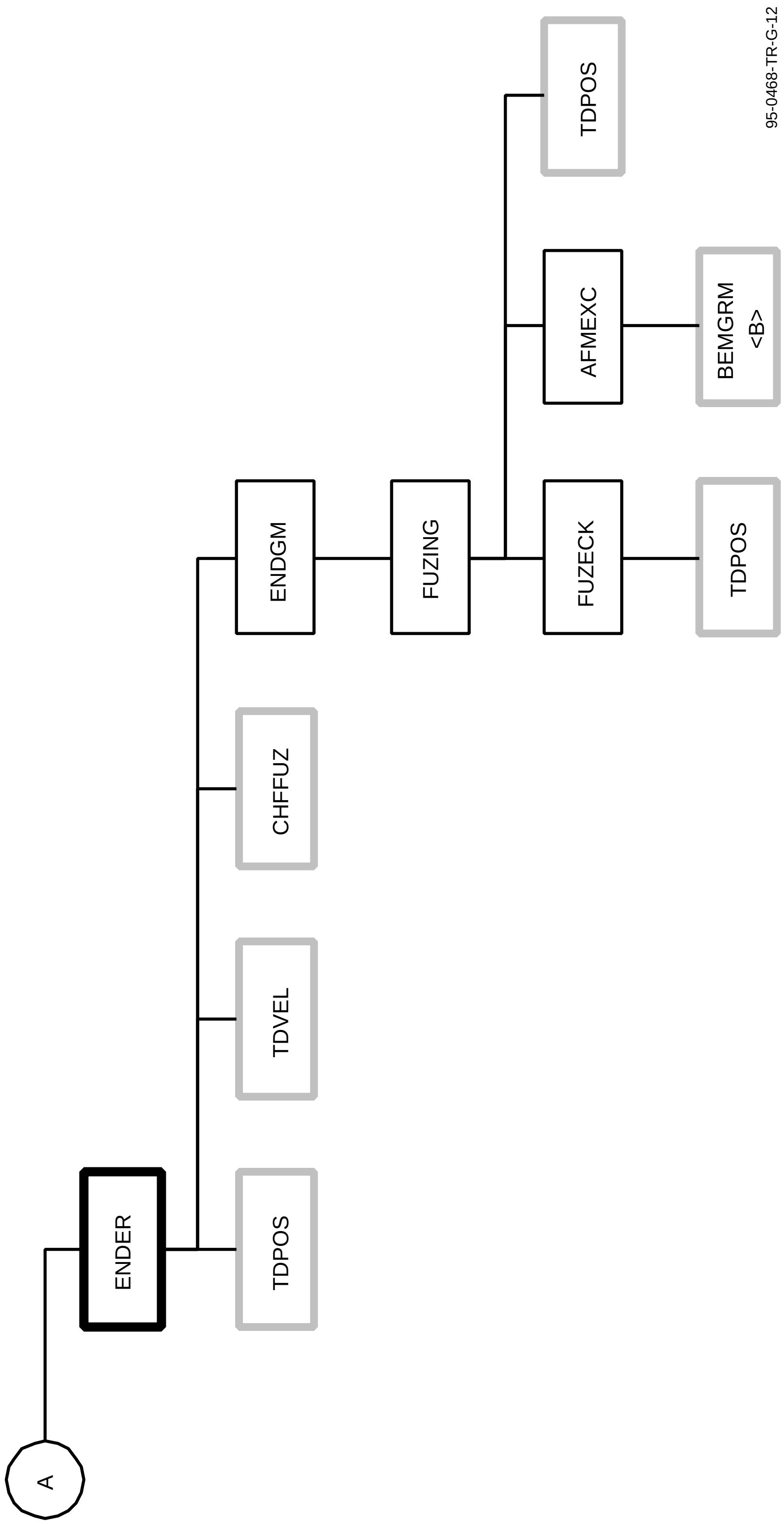

FIGURE 2.9-2. Deceptive Off-Board ECM. (Contd.)

TABLE 2.9-1. Off-Board Deceptive ECM Subroutine Descriptions.

Module Name	Description
ECMINI	Initializes ECM inputs, arrays, pointers, and flags.
BEMGRM	Checks each technique in the ECMD file to see if it is active at the current time against the current radar. Serves as top level routine for ECM calculations
BEMSEN	Sets up engagement features between the jamming aircraft and the ground radar, missile seeker, or missile fuze.
BEMTVL	Calculates relative geometries and orientations between the ground radar and jamming aircraft.
BEMSET	Event message output
BEMSVL	Calculates relative geometries and orientations between the missile seeker and jamming aircraft.
BEMFVL	Calculates relative geometries and orientations between the missile fuze and jamming aircraft. Obtains fuze characteristics.
BEMANT	Provides jamming antenna position, velocity, and orientation.
BEMEXC	Loads the current CM characteristics. These include Doppler, power, phase, polarization, pulse width, and time delay
BEMOUT	Develops the ECM induced voltage in the victim radar receiver for bin masking and swept spot noise.
BEMNZ	Computes the noise-like jamming signals for continuous noise ECM.
TDINI	Initializes TD variables.
TDEXC	Calls subroutines t determine TD signature, position, orientation, and velocity.
SKNSIG	Determines sum and difference channel voltages at victim radar due to TD skin return.
TDDPLY	Updates TD deployment status.
TDPOS	Returns TD position.
TDVEL	Returns TD velocity.
TDROLL	Returns TD orientation.
CHFEXC	Calls chaff routines to execute chaff effects.
CHAFFI	Initializes chaff rocket and chaff cloud jammers.
CHAFCI	Determines number of chaff cloud parcels, the time intervals between parcels, and the position at time of cloud drop.
CHFCLD	Creates and evolves the five member parcels representing a dispersing chaff cloud.
ILLCHF	Calculates one return signal for each scatterer in the cloud using illumination from the jammer antenna.
CHFSIG	Acts as top level executive for computing the radar signals scattered from the chaff cloud.
CLDSIZ	Computes the size of the chaff cloud.
CHFRCS	Calculates chaff cloud RCS.
CHDPLR	Calculates one return signal for each scatterer in the cloud, taking into consideration the rcs growth factor as a function of time.
CHFFUZ	Determines if missile fuzes on chaff.

ECM Deceptive Off-Board Functional Flow

Figures 2.9-3, 2.9-4, and 2.9-5 show the top-level logical flow of the deceptive off-board ECM implementation. Subroutine names appear in the parentheses at the bottom of each process block. The numbered blocks are described below. Since the noise and deceptive

ECM techniques can be used on the TD, most of the algorithms to address their functions are included in figure 2.9-3. Figures 2.9-4 and 2.9-5 expand on the stubs in Figure 2.9-3 for the chaff and towed decoy respectively.

Block 1. The radar mode to jam is extracted from the ECMD file. It can be any (TECMOD=0), the acquisition mode (TECMOD=1), the track mode (TECMOD=2), or jamming to commence after the missile is fired (TECMOD=3).

Block 2. Relative or absolute is set for the various jamming characteristics based on the setting of the "ROA" parameter in the ECMD file. Relative is with respect to the victim radar waveform, while absolute means it is independent of the victim waveform. If the "ROA" parameter is set to one, the value of the characteristic is absolute. If it is zero, the values are relative. For example, DLYROA equal one means that the time delay of the jam signal is absolute. The jamming characteristics set to absolute or relative are frequency, amplitude, phase, polarization, pulse width, and time delay.

Block 3. Environmental values are obtained for the ground radar, missile seeker, or missile fuze by calling BEMTVL, BEMSVL, or BEMFVL, respectively.

Blocks 4, 5, and 6. Relative geometry and orientation between the victim sensor and the jamming aircraft are obtained. This data sets the stage for calculations in blocks 8, 9, and 10.

Block 7. Special calls are made to the fuzing logic to obtain key parameter such as fuze power.

Blocks 8, 9, and 10. The elements of the RADVLU array that are filled are: Doppler due to TX and jammer aircraft velocity; power returned to the jamming aircraft; phase at the jamming aircraft due to TX and aircraft separation; received power from the victim radar at the aircraft (includes victim sensor and jammer antenna attenuations); pulse width of victim radar transmitter; relative closing velocity between the victim sensor and the jamming aircraft; victim receiver voltage gains in the direction of the jamming aircraft for the sum, azimuth difference, and elevation difference channels respectively; and target RCS in the direction of the victim sensor.

Blocks 11, 12, and 13. The end result of these blocks is to provide the ECM waveform. Block 12 is necessary in the alternate route flow to set the jam on-time to zero if it is not specified base on the threat mode. The ECM waveform parameters—either relative or absolute depending on the "ROA" parameters—are Doppler, power, phase, polarization, pulse width, and time delay.

Block 14. The number of techniques is specified in the ECMD file. As illustrated earlier, the bin masking jamming treated the jamming in the individual range gates and Doppler bins as a technique. Thus, there were twelve jamming techniques specified, and the jamming power for each of the techniques must be added to the sum of the power of the previous techniques.

Blocks 15, 16, and 17. The parameter ANTSEL in the ECMD file selects either an omni-directional antenna (ANTSEL .GT. 0) or a specific antenna with a specific pattern (ANTSEL .LE. 0). If the antenna is omni-directional, the orientation of the jamming aircraft and victim sensor is not important. For the latter case, the jamming antenna which is pointed most directly at the victim sensor is determined. The antenna's location in inertial coordinates is obtained and, at a later time, its gain in the direction of the victim sensor is established.

Block 18. The jammer antenna inertial coordinates with respect to the victim sensor are obtained.

Block 19. Special signals are transferred to the ESAMS bus. These include victim sensor wavelength, loss factors, and antenna error slopes.

Block 20. The call to BEMOUT generates the sum and difference channel complex voltages, apparent range, and Doppler shift of the jamming signal at the victim sensor. The signal has been attenuated appropriately for the transmitter and receiver antenna gains.

Blocks 21, 22, and 23. These blocks show that bin masking and swept spot noise are generated using the same code but that continuous noise is treated differently. With the first two, the noise voltages are obtained in a deterministic fashion using the radar range equation and other pertinent features such as transmitter and receiver gains. Since these two jamming techniques are played in a repeater mode, this methodology is reasonable.

Continuous noise is not used in a repeater, or relative jamming, fashion. Instead, it is employed in an absolute fashion and developed as a noise-like signal. The amplitude of the sigma in each section is a stochastic variable, giving a noise-like representation.

Block 24. Since the jamming is developed for the different techniques and also in sections of the pri for the continuous noise, a check is made and power reduced if necessary, to insure that the power available is not exceeded.

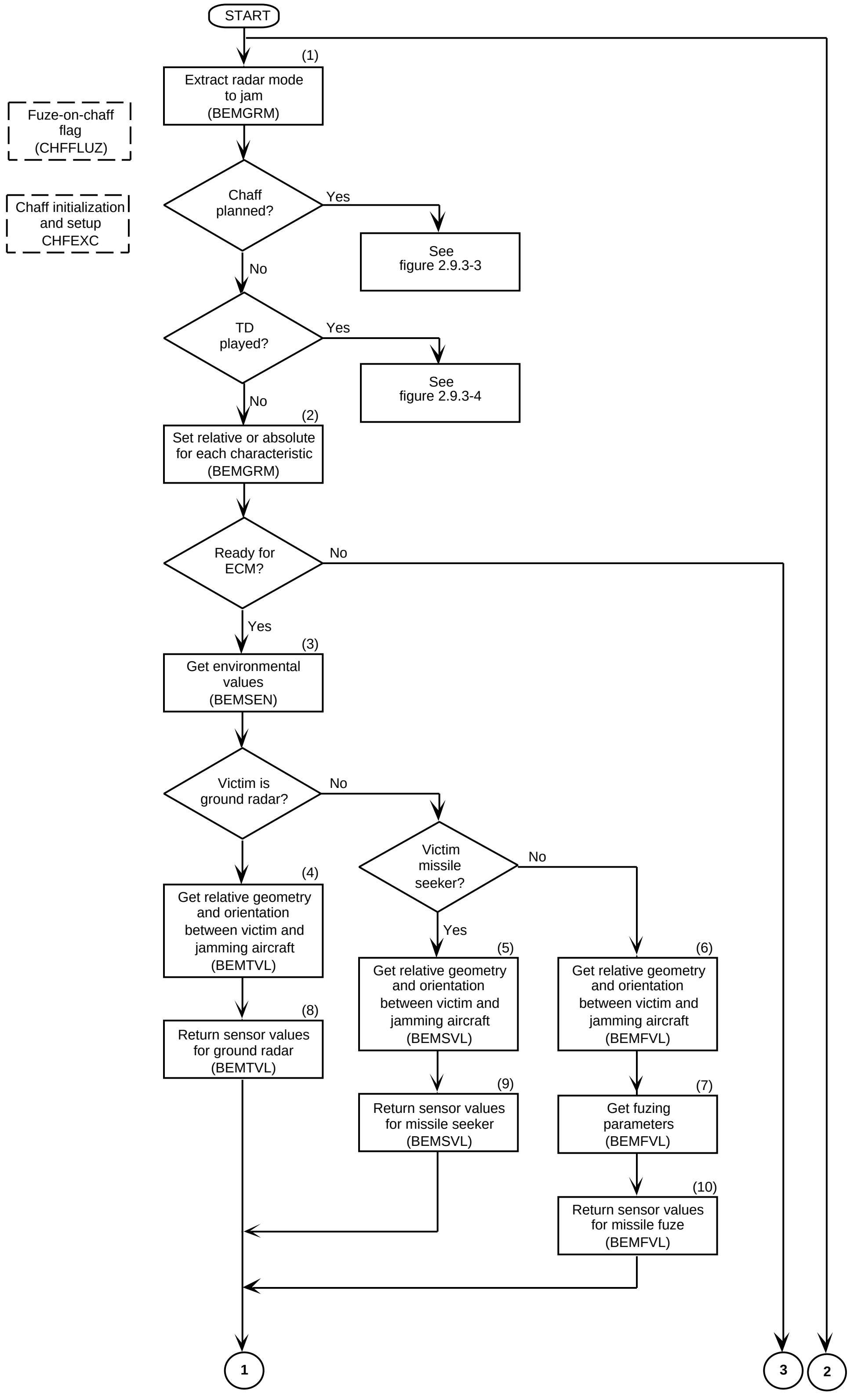

FIGURE 2.9-3. Off-Board Deceptive ECM Functional and Data Flow Diagrams.

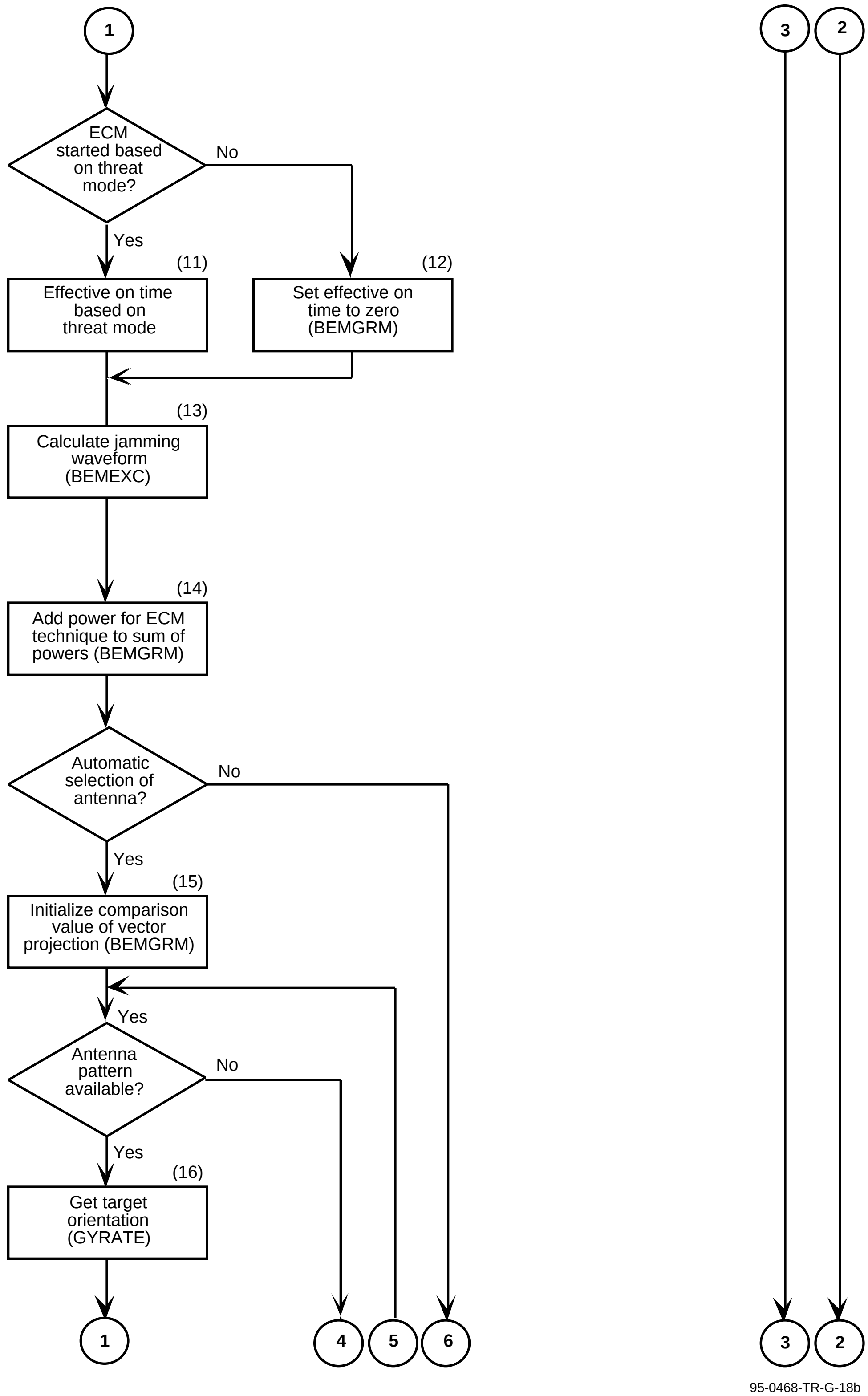

FIGURE 2.9-3. Off-Board Deceptive ECM Functional and Data Flow Diagrams. (Contd.)

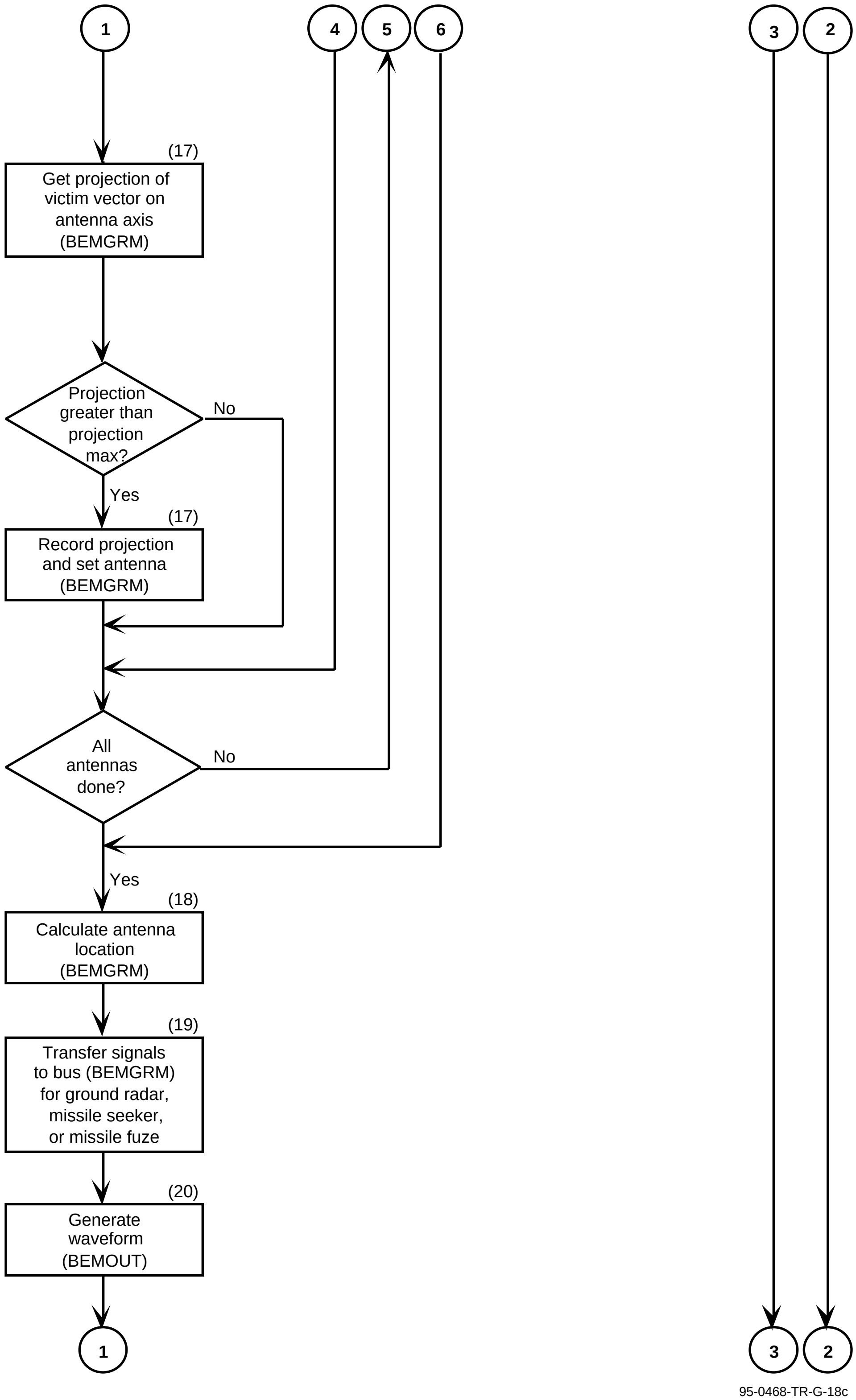

FIGURE 2.9-3. Off-Board Deceptive ECM Functional and Data Flow Diagrams. (Contd.)

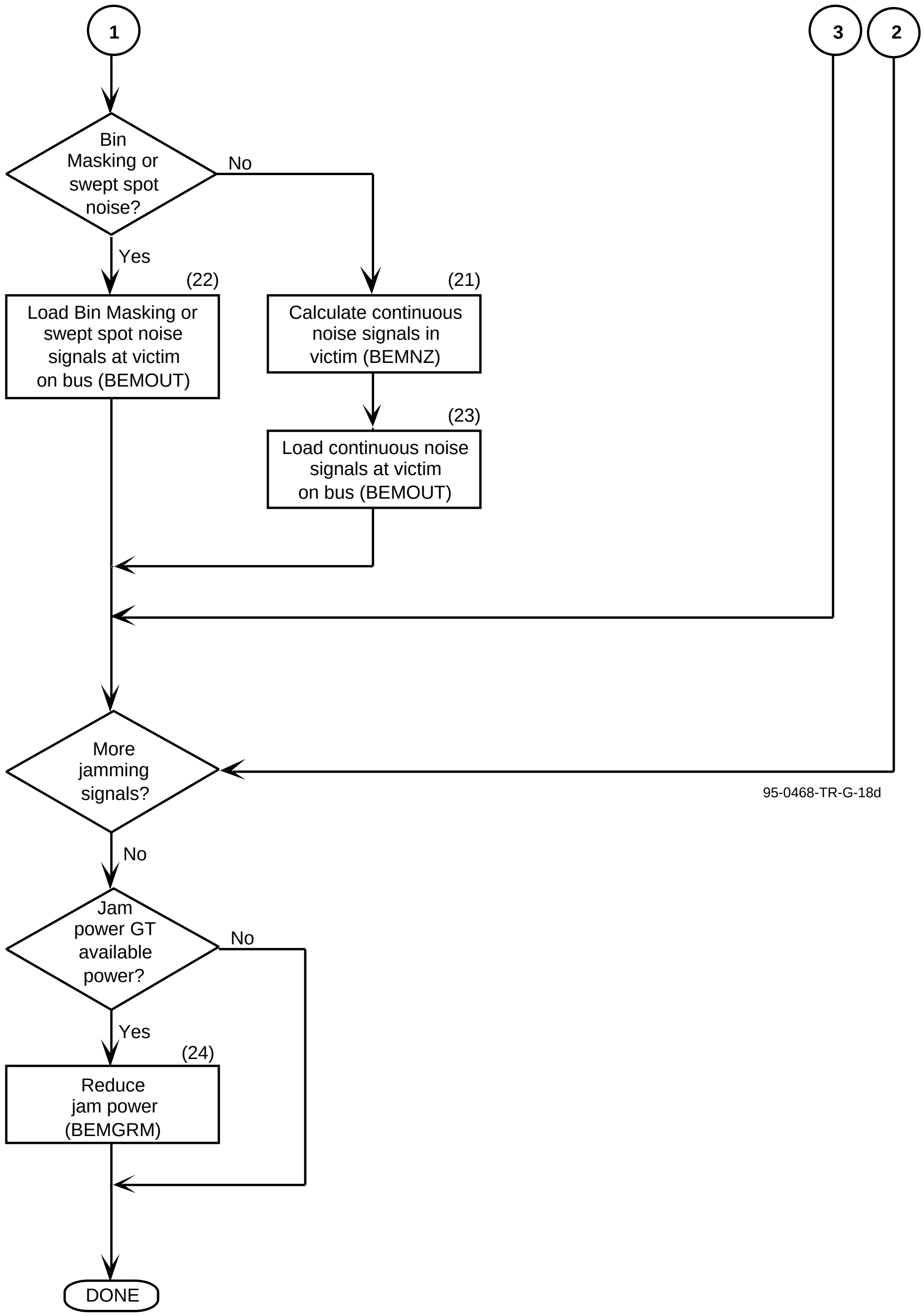

FIGURE 2.9-3. Off-Board Deceptive ECM Functional and Data Flow Diagrams. (Contd.)

Figure 2.9-4 shows the flow of TD data that is necessary to obtain the TD skin return impact on the victim radar. The elements that are necessary are the TD range, Doppler, pulse width, and complex voltages entering the victim radar's sum and difference channels. (The actions in each block are simple enough for the text in the block to fully describe the actions.)

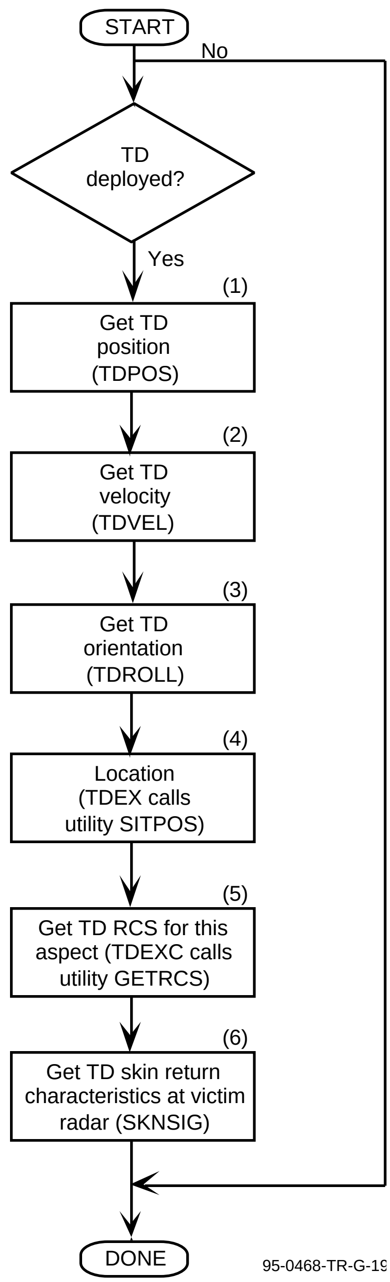

FIGURE 2.9-4. Towed Decoy Data Flow.

The flow of data in Figure 2.9-4 also allows the determination to be made as to whether or not the missile would fuze on the TD. If the parameter FZONTD in the ECMD file is set to one, then the missile is allowed to fuze on the TD. Characteristics of the TD flight, such as its position, velocity, orientation, and skin return, allow the determination to be made.

The flow of chaff data up to BEMGRM is shown in Figure 2.9-5. To set the stage for the determination of chaff impact, CHFEXC is called by GORUN prior to BEMGRM being called so that the chaff data are provided. GORUN also calls CHFFUZ to show if fuzing on chaff has occurred. The numbered blocks in Figure 2.9-5 are described below.

Block 1. CHFSIG calls subroutines to determine the position and velocity of the victim radar, which may be either the ground radar or missile seeker. It assumes that illumination is provided by the ground system. Allowances are made for both monostatic and bistatic ground radars. The bistatic ground radar uses separate transmitting and receiving systems.

Block 2. CLDSIZ calculates the linear size of the chaff cloud and the associated cross sectional areas for the front, side, top, transmitter view, receiver view, and the bistatic view.

Block 3. CHFRCS calculates the chaff cloud RCS based on the dispersed cloud scatterer RCS and the bistatic presented area of the chaff cloud as seen by the receiver. The input variable RCSTOT is the maximum scatterer RCS for a dispersed cloud viewed broadside. CHFRCS accounts for aspect angle dependency with presented area.

Block 4. CHDPLR calculates one return signal for each scatterer in the chaff cloud. For each parcel, the RCS growth factor is computed as an exponential function of the time since parcel drop. After this, the illuminator and receiver antenna gains are obtained from calls to FEND. The scatterer sum channel signal, difference channel signals, Doppler, pulse width, and range are then obtained using the usual radar equations.

Block 5. ILLCHF calculates one return signal for each scatterer in the chaff cloud. This routine is very similar to CHDPLR, except that it uses the jammer antenna gain instead of the ground radar.

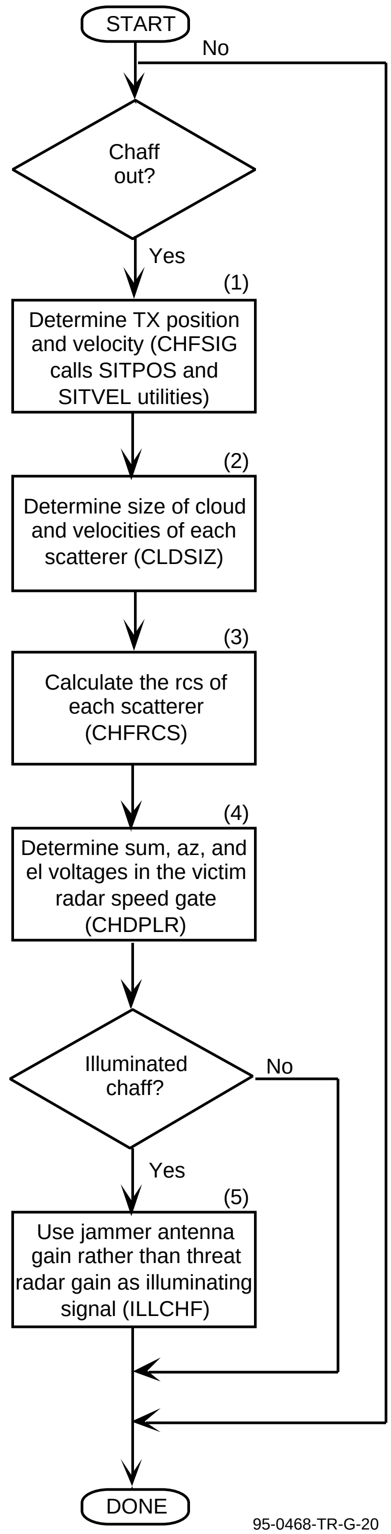

FIGURE 2.9-5. Chaff Data Flow.

Subroutine Flow Charts

Functional flow diagrams of the ECM subroutines which support off-board deceptive ECM are shown in Figures 2.9-6 through 2.9-32. Many of the subroutines have already been documented in FEs 1.3.1.1 and 1.3.2.1. The functional flow diagrams and I/O data tables for those subroutines are not repeated in this FE. The flow diagrams and I/O data tables for those subroutines are listed and referenced to the FE where they are shown.

There are five different areas in ESAMS which can be impacted by ECM: (1) Waveform driven ground radars during acquisition; (2) waveform driven ground radars during tracking; (3) time stepped TWS radars during acquisition and track; (4) missile seeker operation; (5) and missile fuzing.

The waveform driven ground radars use WFAPDT, WFADP, WCFAR, and FTACQ. WFAPDT implements the acquisition mode detection logic for this model. Based on the RDRD data file variable XINPRC, it implements one of the following modes: Doppler only search, range only search, Doppler followed by range search, and Doppler range simultaneous search. If there are not multiple Doppler bins and range gates to be searched, then WFAPDT specifies that a fixed threshold will be used.

WFAPDT calls WFADP with the information as to whether a fixed or cell averaging CFAR is used. WFAPDT calculates the fixed threshold level and passes it to WFADP. Since WFAPDT has previously been called by BEMGRM, it passes jam energy information to WFADP.

If a fixed threshold is used, WFAPD calls FTACQ. FTACQ determines if there is enough power—including that from the jammer—to exceed the threshold. If there is, the detection flag is set to one. As mentioned previously, the jamming could cause a strobe rather than a blip. In this case, the model resolves as best it can to obtain data to launch the missile (see Reference [34]).

If a CFAR mask is used, WFADP calls WFCFAR to establish the threshold, which is dependent on whether or not Bin Masking is employed. WFCFAR samples specified bins, and the detection threshold is set as a function of probability of false alarm, number of cells sampled, and the noise from the sampled cells.

Subroutines SKRCPI and WFTCPI interface with jamming code through the subroutine GENEXC. SKRCPI and WFTCPI are the Coherent Processing Interval (CPI) code for the seeker and ground radar tracking mode respectively. The CPI code is the lowest level of processing, followed by sequence and group processing. Sequence processing, for example, keeps a running total of angle, range, and Doppler errors plus the number of errors accumulated. The Group level then averages the data and furnishes this information to the appropriate subroutines so that angle, range, and Doppler "gates" are repositioned.

Subroutine SKRCPI also has some ECCM that would be appropriate to noise jamming. Some of the seeker systems have a surge detector. The presence of this detector is identified by the following parameters in the RDRD file:

SRGWIN—Surge detector filter time constant
THRSHS—Surge detection threshold
SRGFCT—Minimum time after track for surge declaration

If a surge detector is specified, then SKRCPI calls HOJCHK to determine if home-on-jam should be implemented. The HOJCHK subroutine checks voltage level signals in the Doppler guard gates to see if the HOJ threshold has been exceeded. If so, the Doppler gate can be frozen, and HOJ tracking implemented. This ECCM will be thoroughly discussed in the Doppler tracking VSDR for ESAMS 2.7.[1]

As mentioned previously, WFTCPI provides interface to the ECM techniques for the waveform driven ground radar tracking. ECCM techniques employed by the ground radar are the following:

1. Range Blanking Pulse. The logic for this technique is contained at the CPI level.
2. Range Gate Repositioning. If selected, this option will reposition the range gate to the position of the guard gate alarm. This logic is contained in subroutine ARGPOA.
3. Range Rate/Doppler Comparisons. This technique is available to any system that tracks Doppler and range gate rate. A check is made of the difference between the range gate rate and the closing rate given by (wavelength*Doppler/2.0). If the difference between these values exceeds the threshold given by RDOTVT, then the comparison alarm is set. Note that the alarm threshold is input in meters per second. This check is disabled if the alarm threshold is zero.
4. Doppler Gate Repositioning. If selected, this option will reposition the Doppler gate as determined by the logic in subroutine AVGPOA.

These techniques are interfaced through a call to subroutine WFTCCM from WFTCPI. As mentioned earlier, the ECCM code is part of the tracking VSDRs.

For the time-stepped TWS systems, TWSEC calls GENEXC which in turn calls BEMGRM when ECM is to be employed. Presently, there is no explicit ECCM code for the TWS systems as there is for other ground trackers and the seekers. Finally, there is the option to introduce jamming into the missile fuze through a call from AFMEXC to BEMGRM. The functional flow diagrams for the off-board deceptive ECM follow.

TABLE 2.9-2. Subroutine Flow Diagram Cross Reference.

Subroutine	FE under which flow diagram is contained
ECMINI	2.5-3a
BEMGRM	2.5-3b
BEMANT	2.5-3c
BEMTVL	2.5-3d
BEMSVL	2.5-3e
BEMFVL	2.5-3f
BEMSEM	2.5-3g
BEMEXC	2.5-3h
BEMNZ	2.5-3i
BEMOUT	2.5-3j
BEMSET	2.5-3a

1. This document is not yet published.

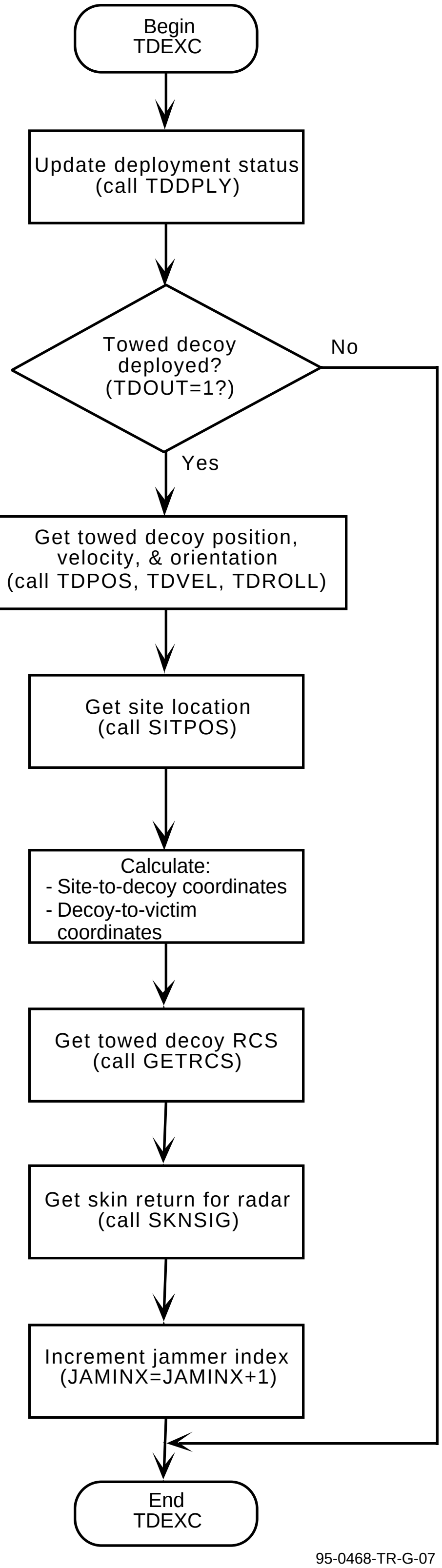

FIGURE 2.9-6. Functional Flow Diagram for Subroutine TDEXC.

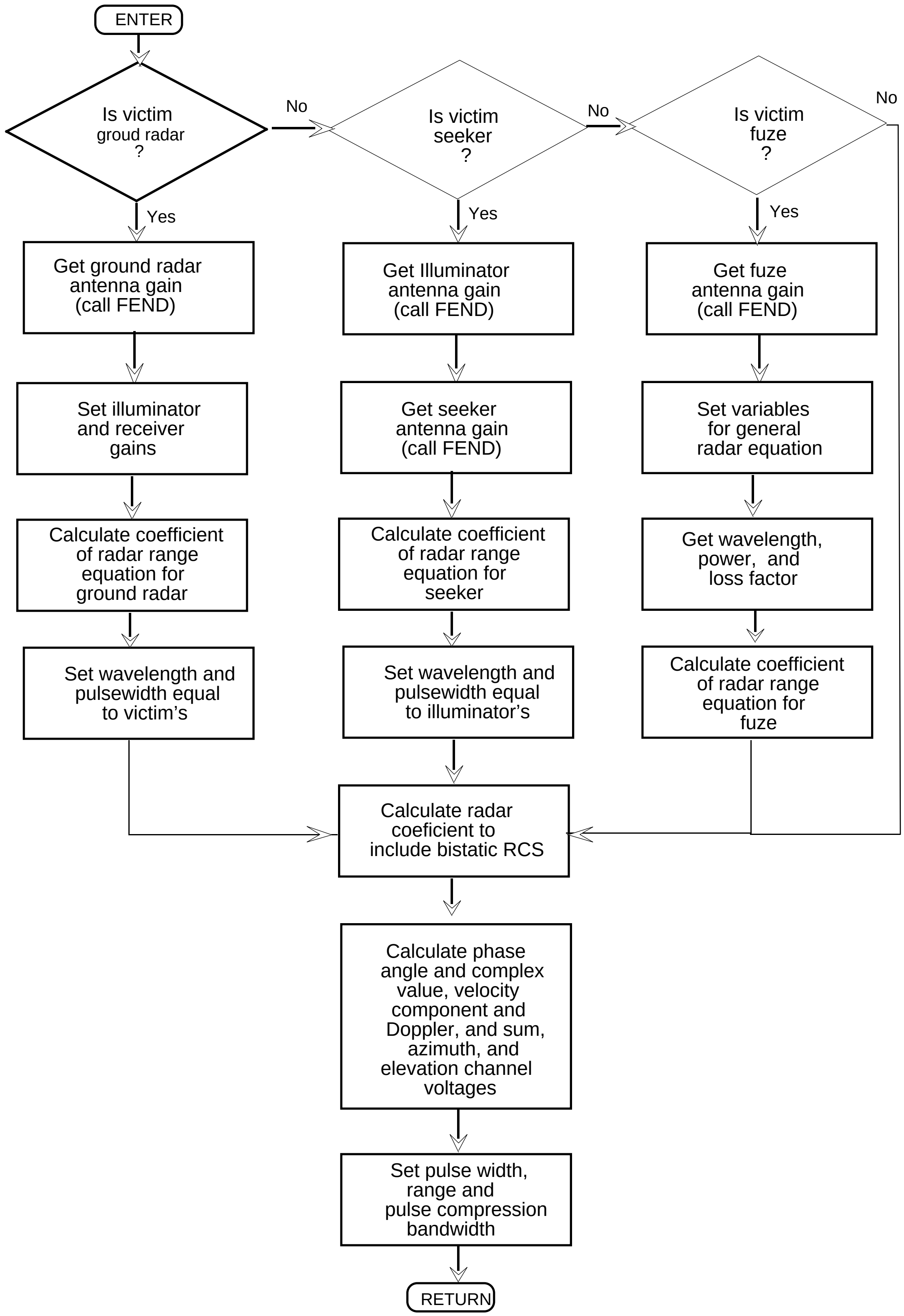

FIGURE 2.9-7. Functional Flow Diagram for Subroutine SKNSIG.

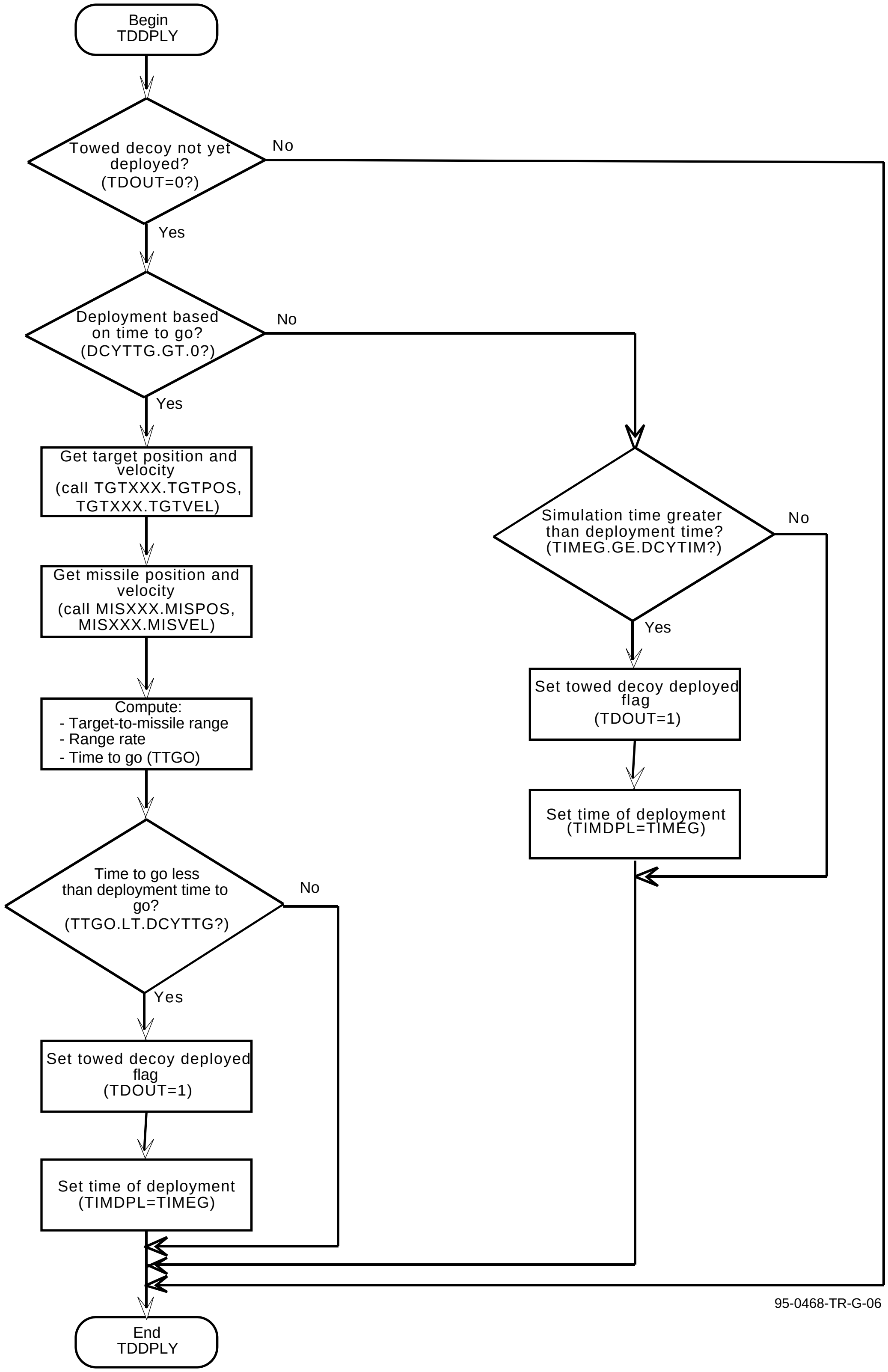

FIGURE 2.9-8. Functional Flow Diagram for Subroutine TDDPLY.

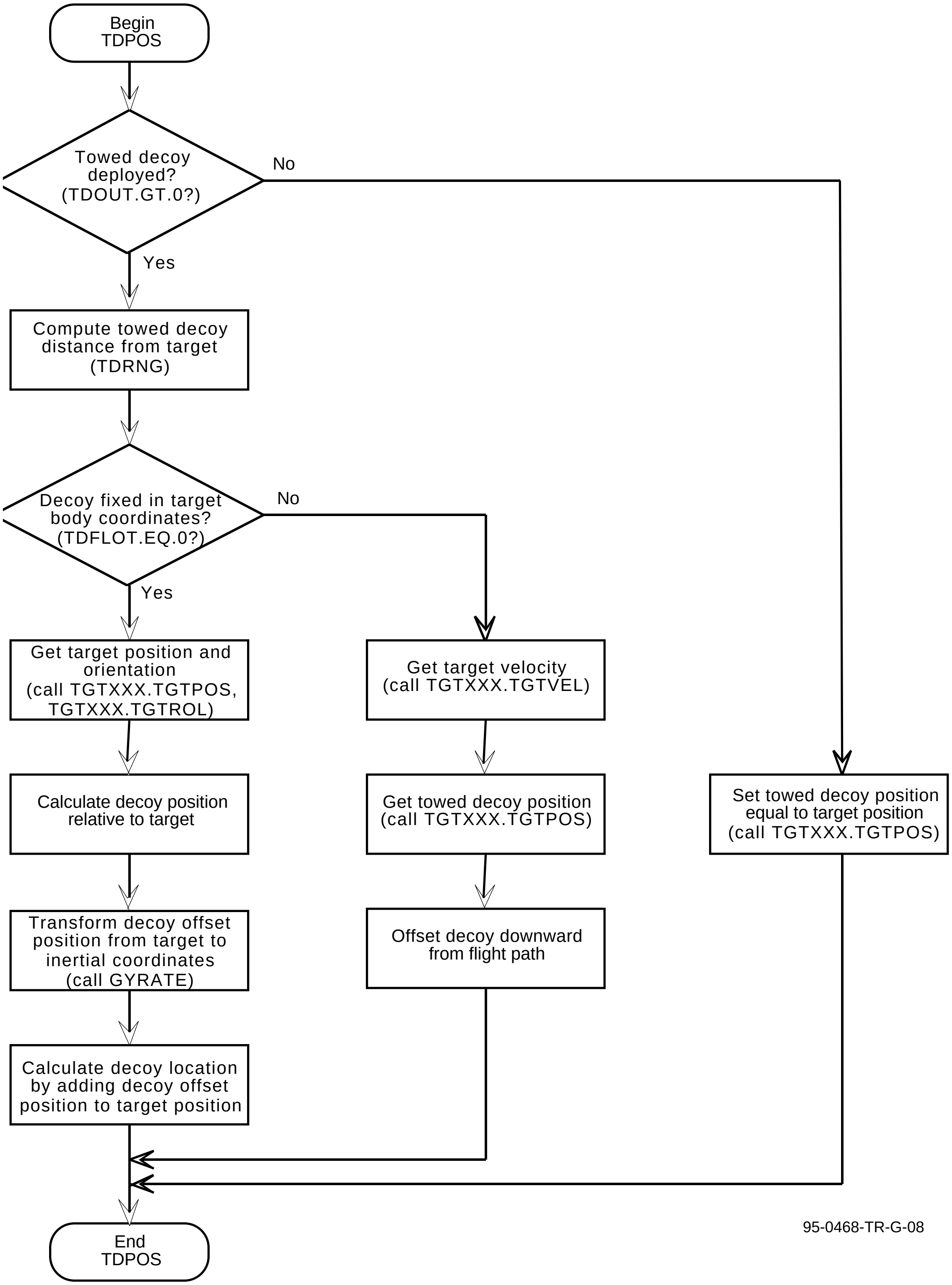

FIGURE 2.9-9. Functional Flow Diagram for Subroutine TDPOS.

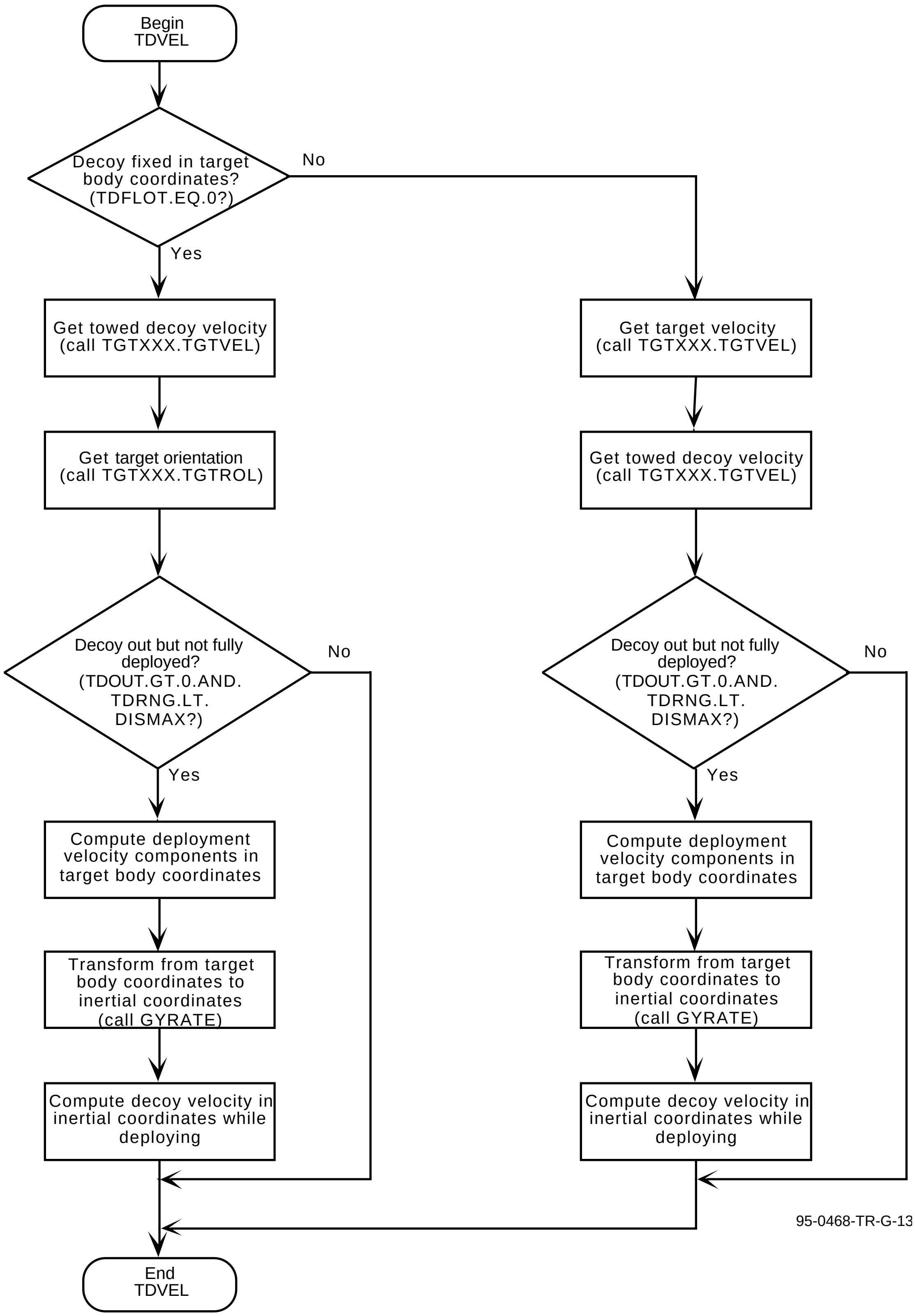

FIGURE 2.9-10. Functional Flow Diagram for Subroutine TDVEL.

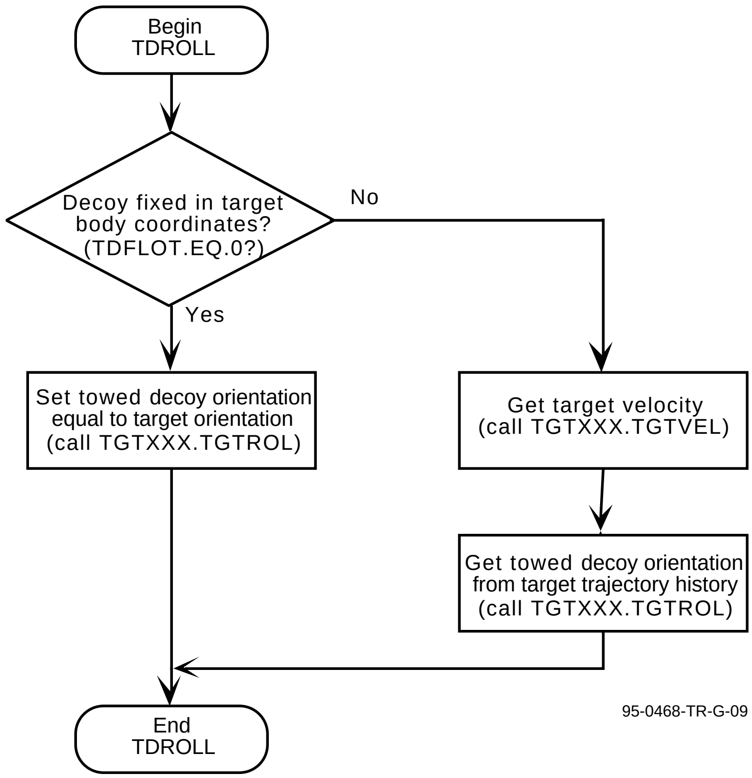

FIGURE 2.9-11. Functional Flow Diagram for Subroutine TDROLL.

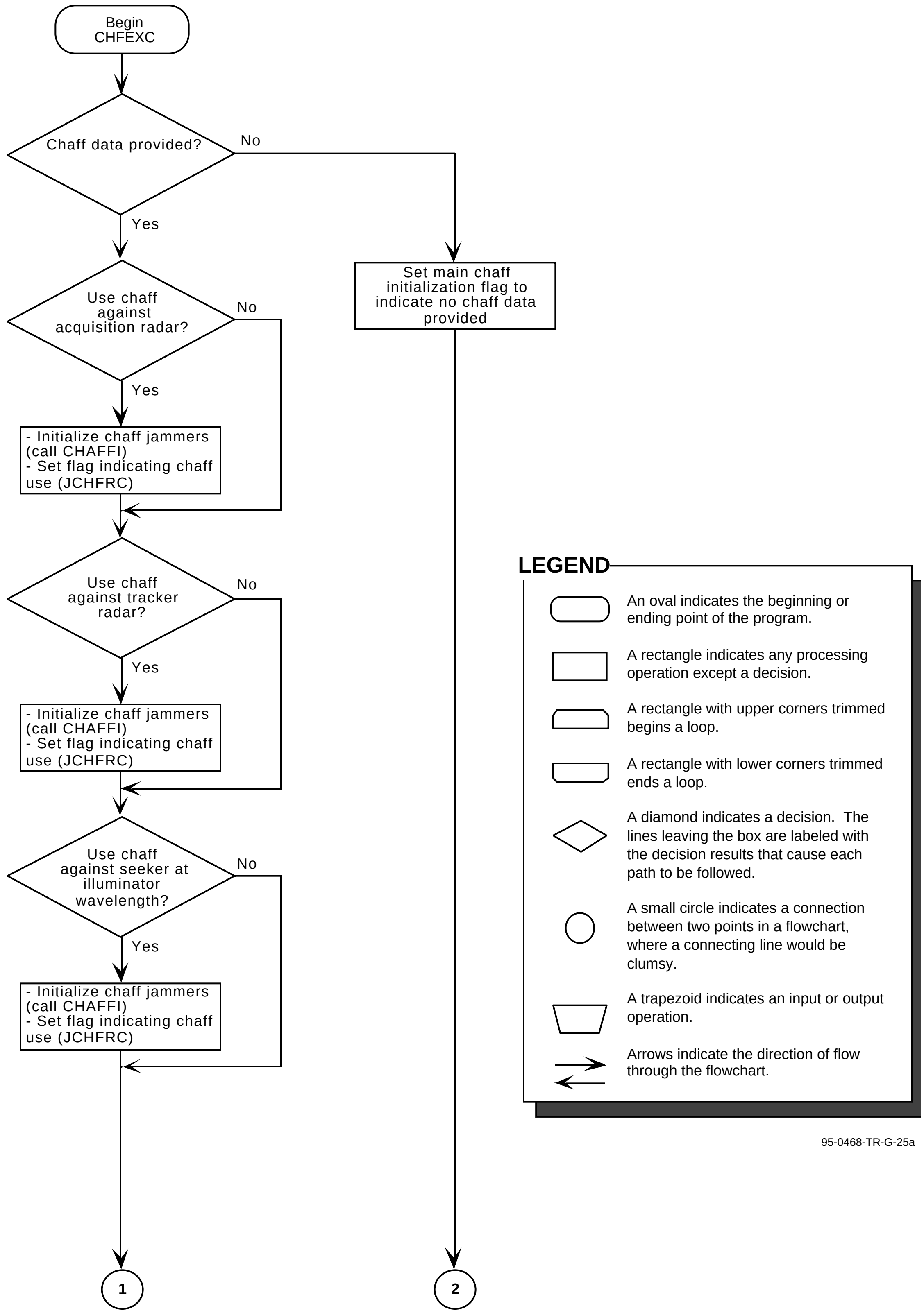

FIGURE 2.9-12. Functional Flow Diagram for Subroutine CHFEXC.

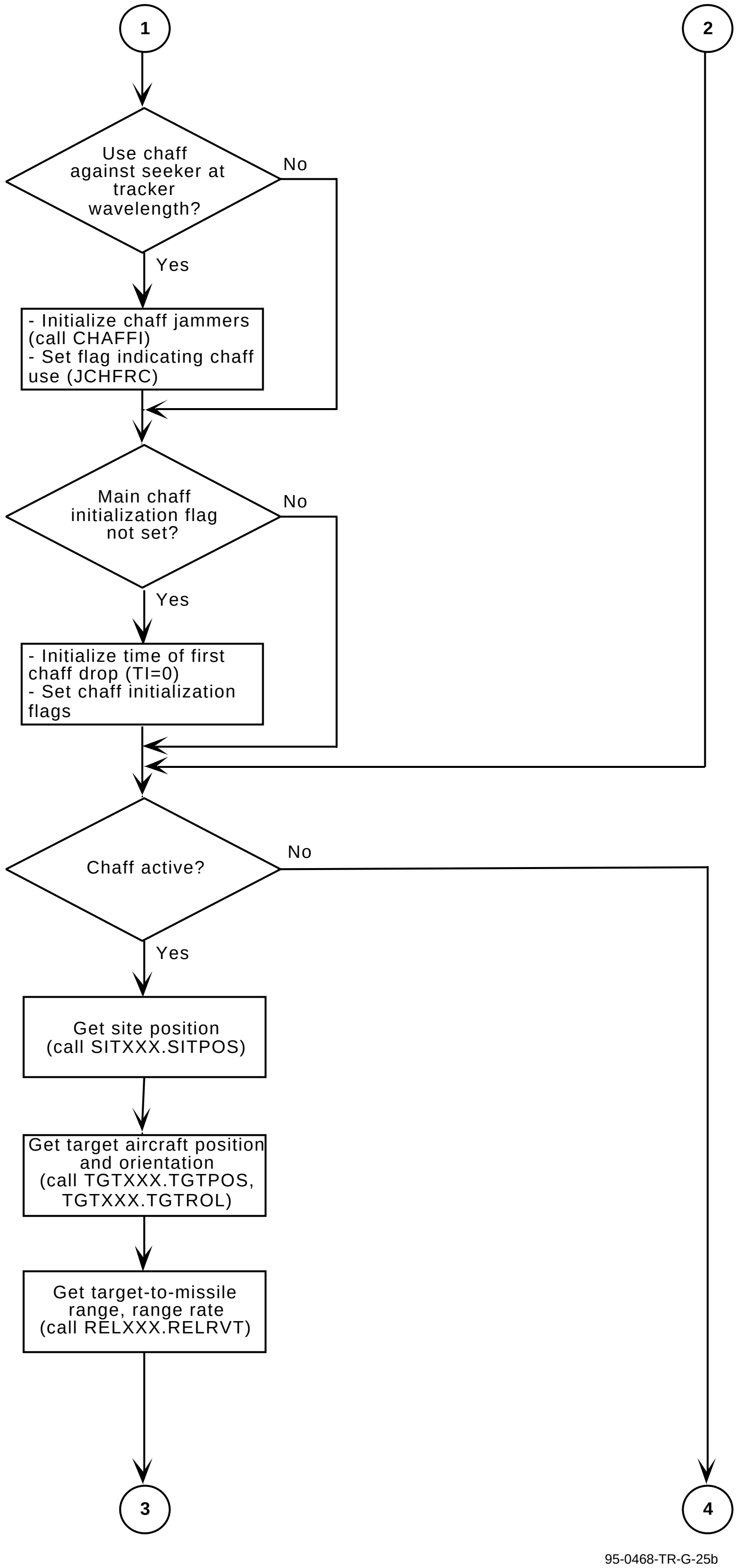

FIGURE 2.9-12. Functional Flow Diagram for Subroutine CHFEXC. (Contd.)

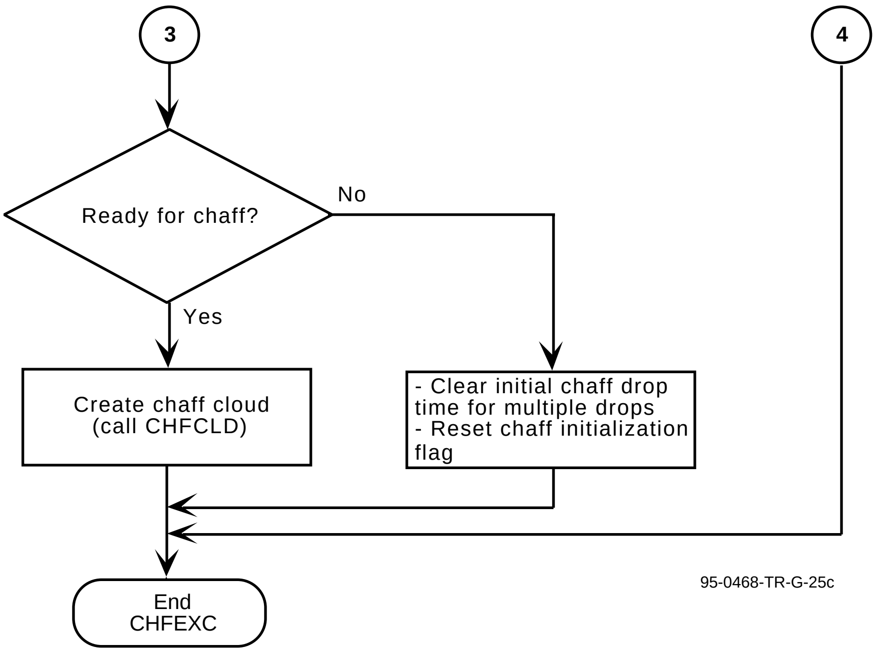

FIGURE 2.9-12. Functional Flow Diagram for Subroutine CHFEXC. (Contd.)

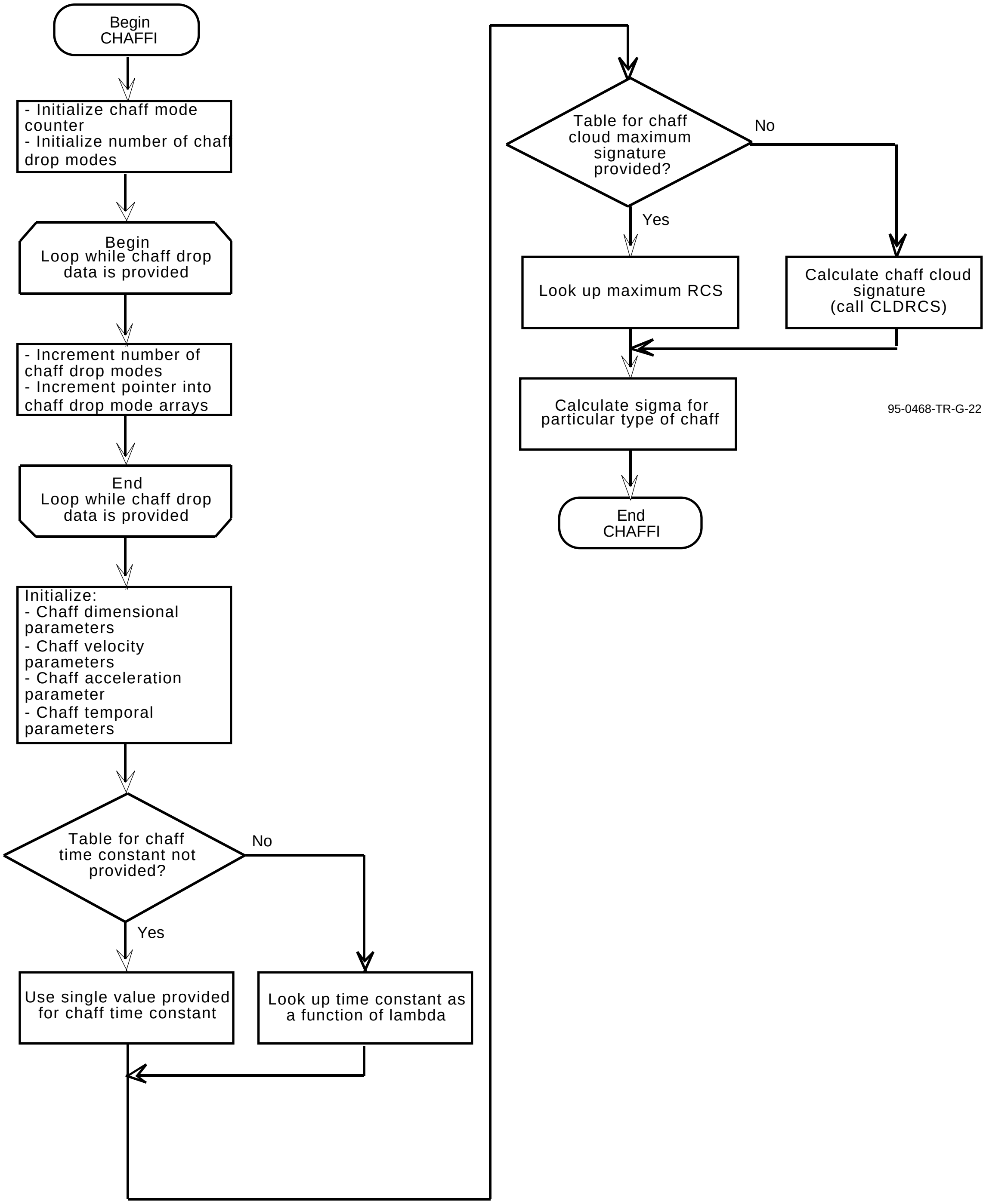

FIGURE 2.9-13. Functional Flow Diagram for Subroutine CHAFFI.

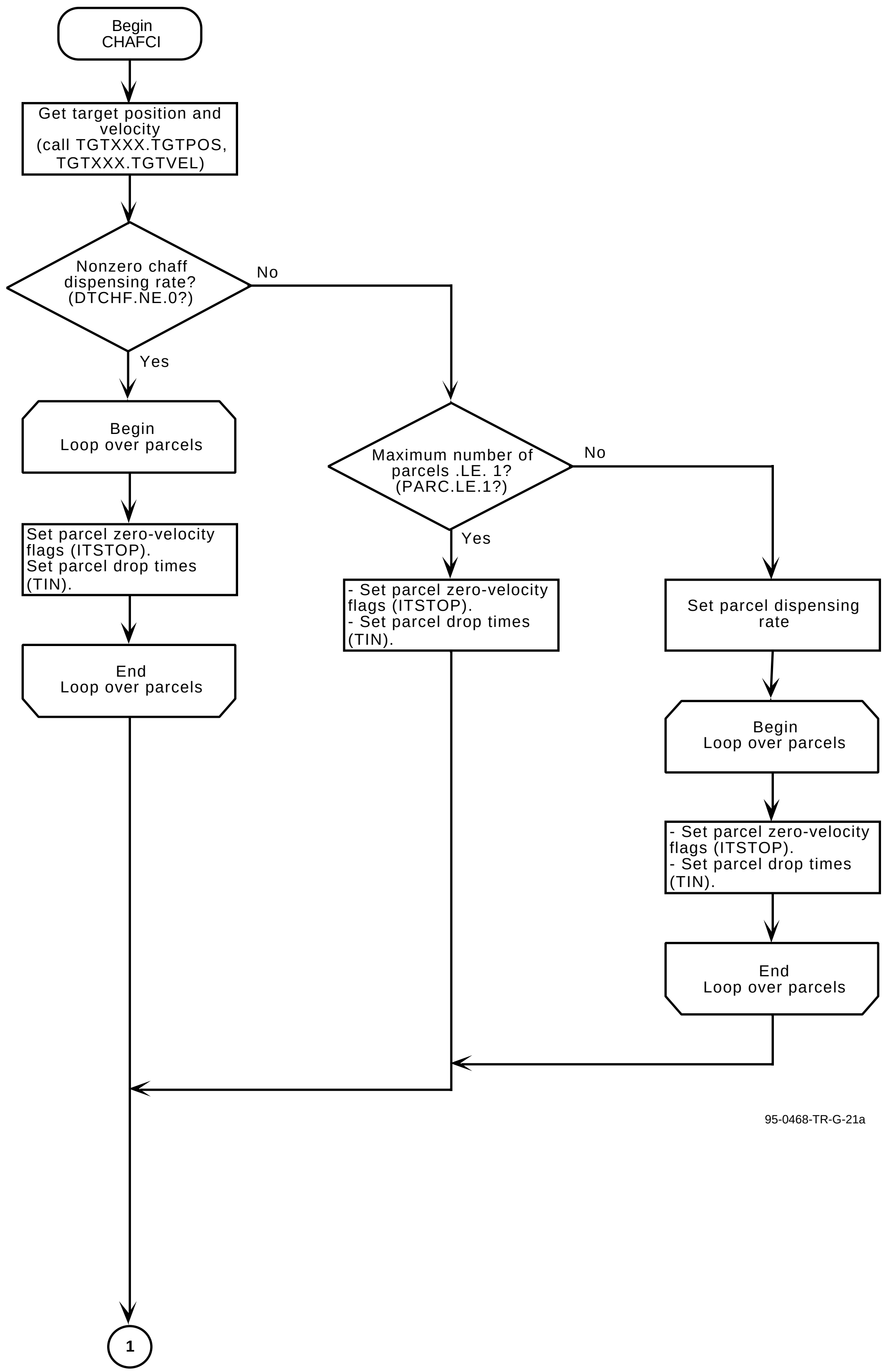

FIGURE 2.9-14. Functional Flow Diagram for Subroutine CHAFCI.

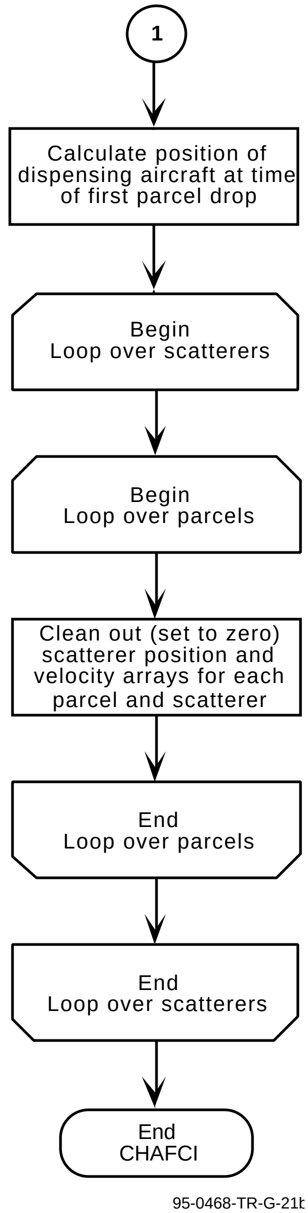

FIGURE 2.9-14. Functional Flow Diagram for Subroutine CHAFCI. (Contd.)

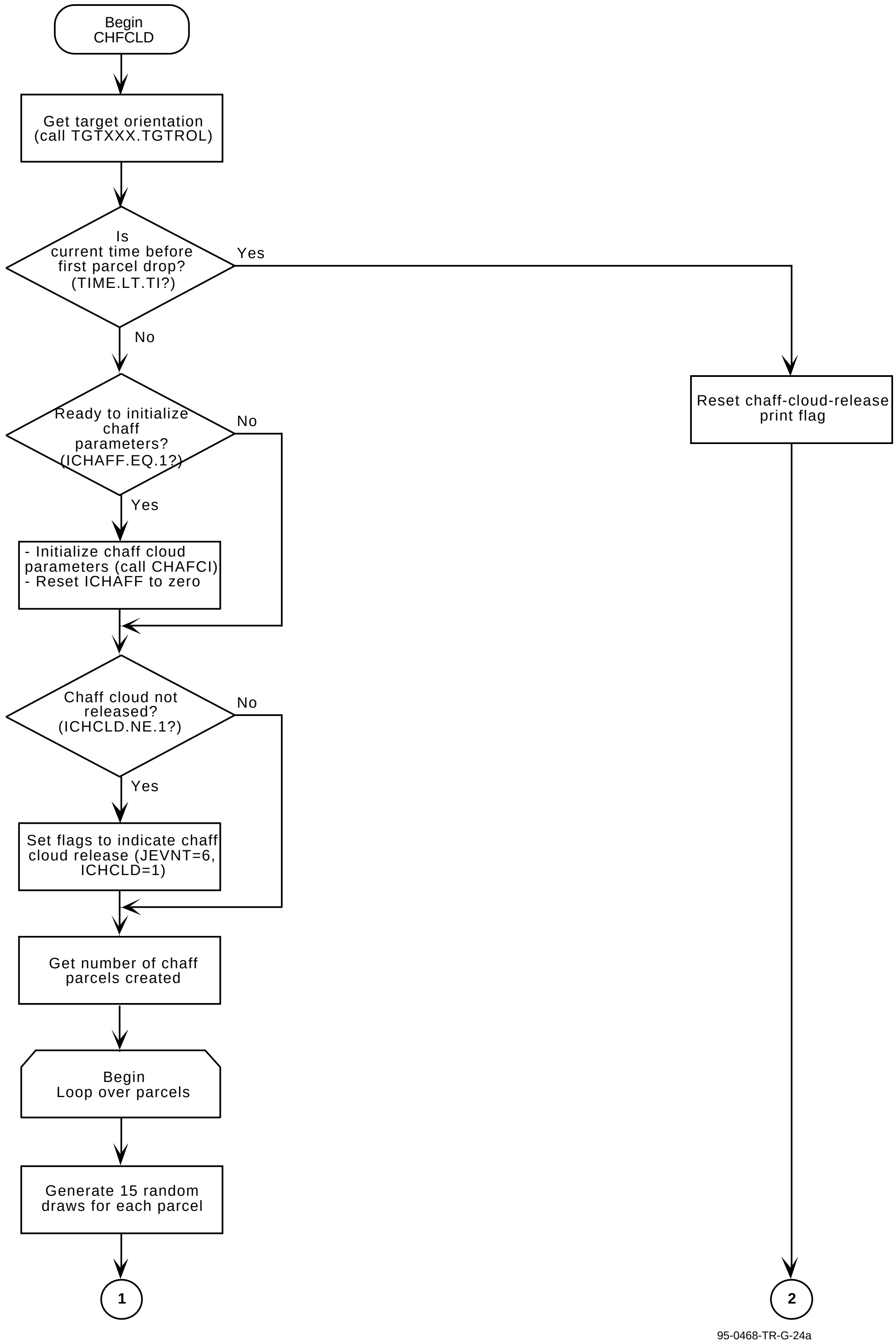

FIGURE 2.9-15. Functional Flow Diagram for Subroutine CHFCLD.

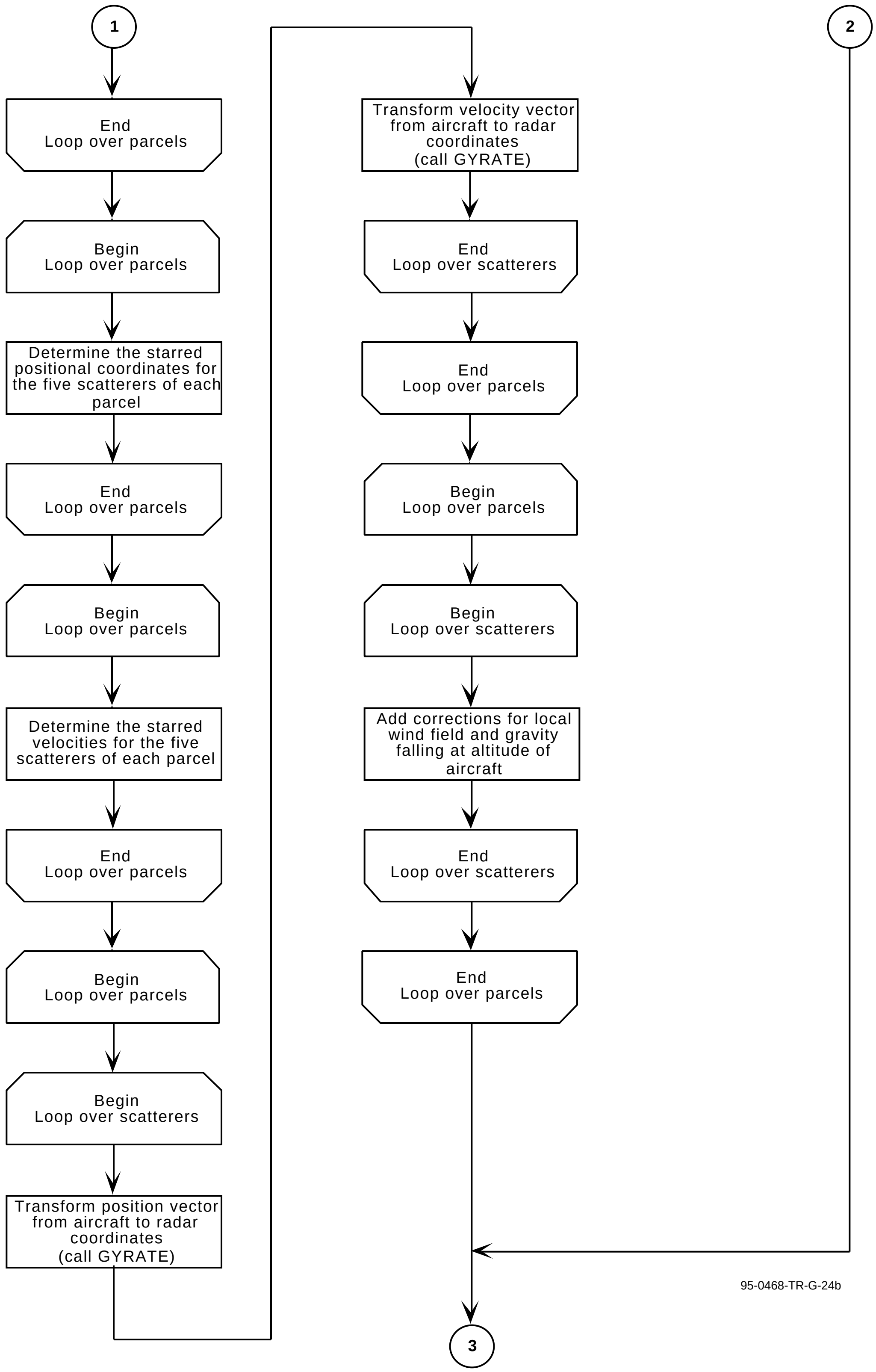

FIGURE 2.9-15. Functional Flow Diagram for Subroutine CHFCLD. (Contd.)

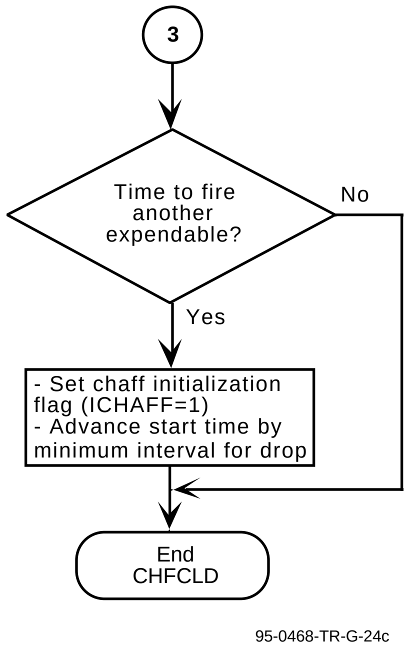

FIGURE 2.9-15. Functional Flow Diagram for Subroutine CHFCLD. (Contd.)

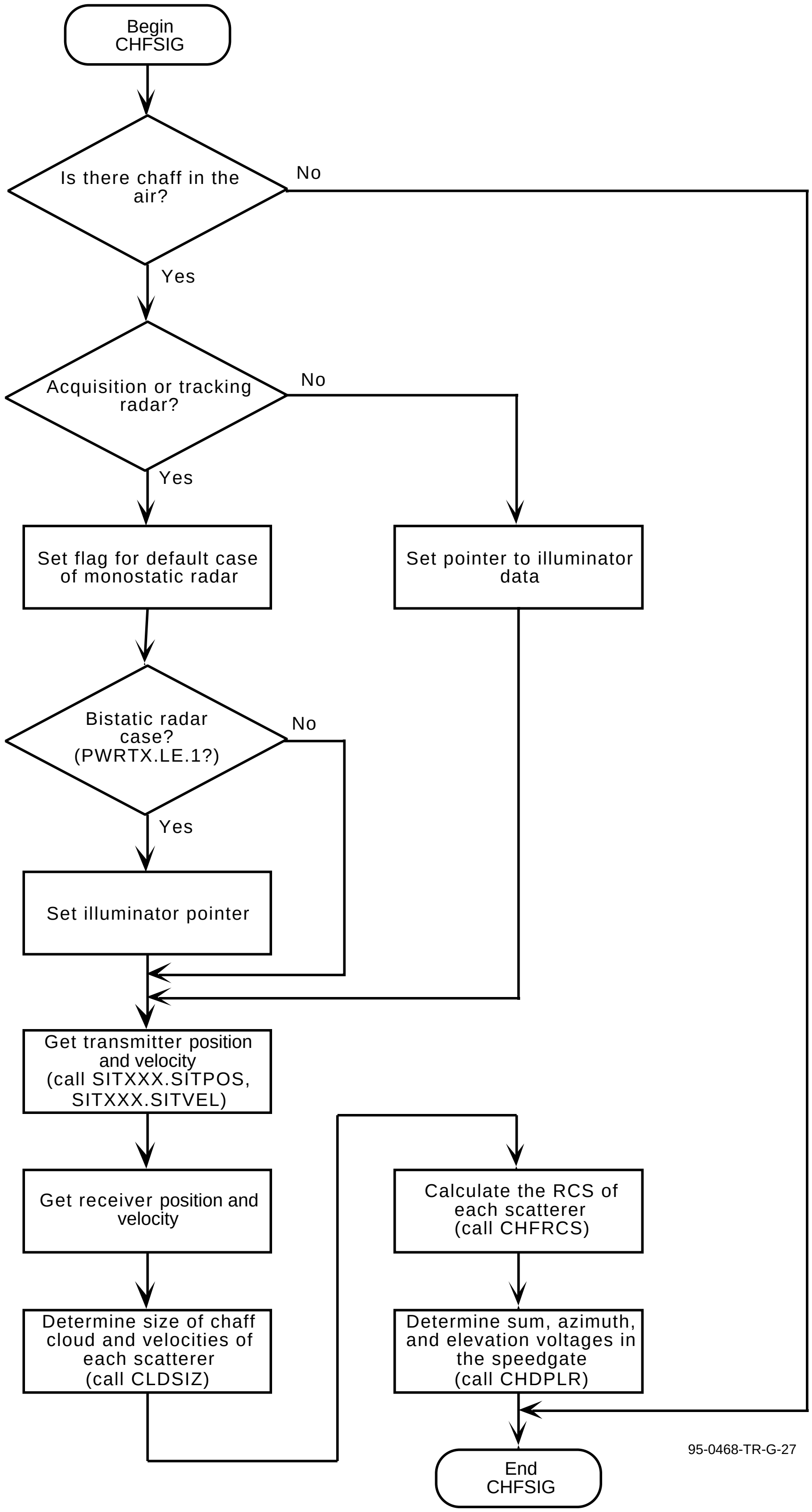

FIGURE 2.9-16. Functional Flow Diagram for Subroutine CHFSIG.

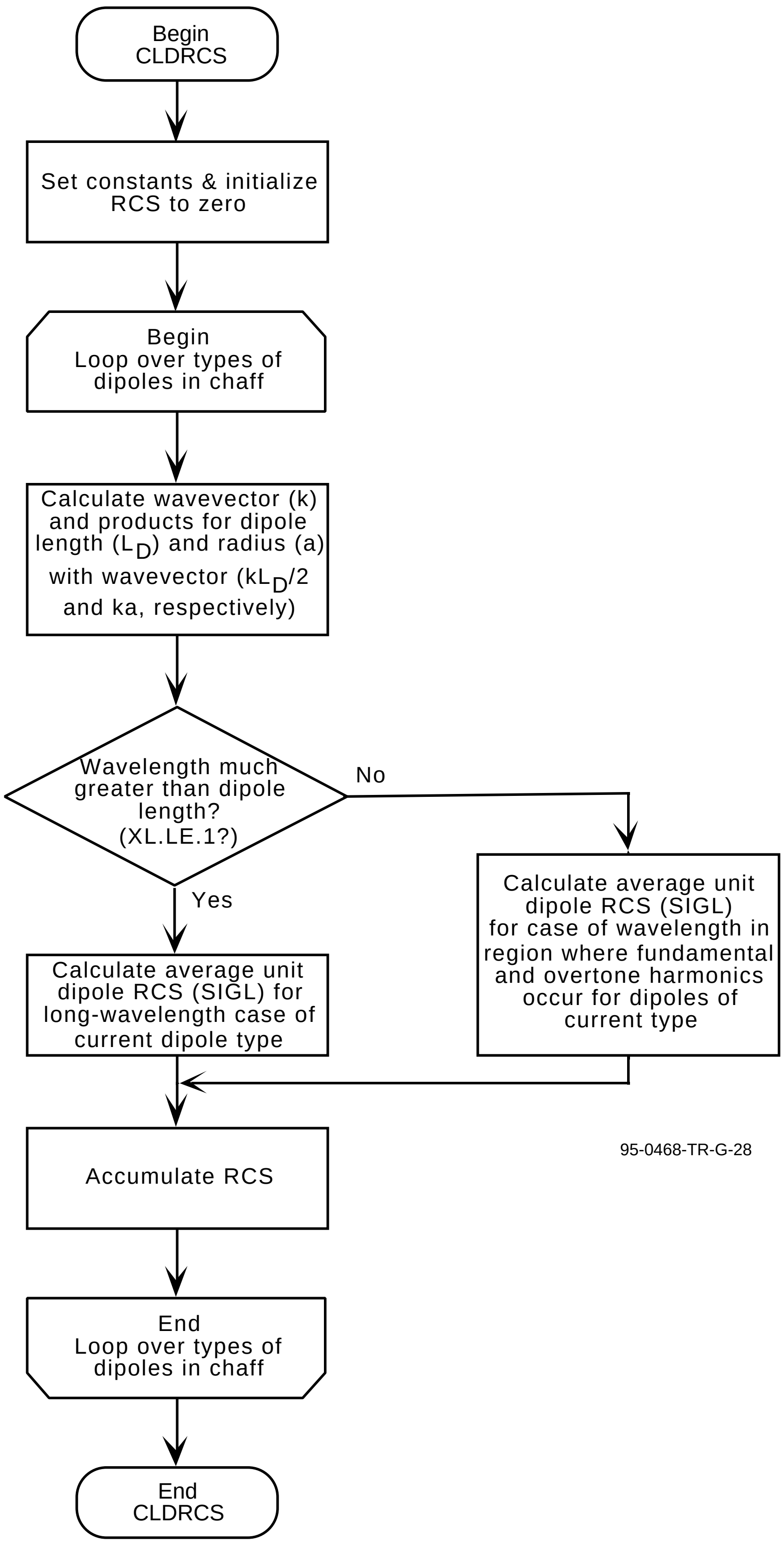

FIGURE 2.9-17. Functional Flow Diagram for Subroutine CLDRCS.

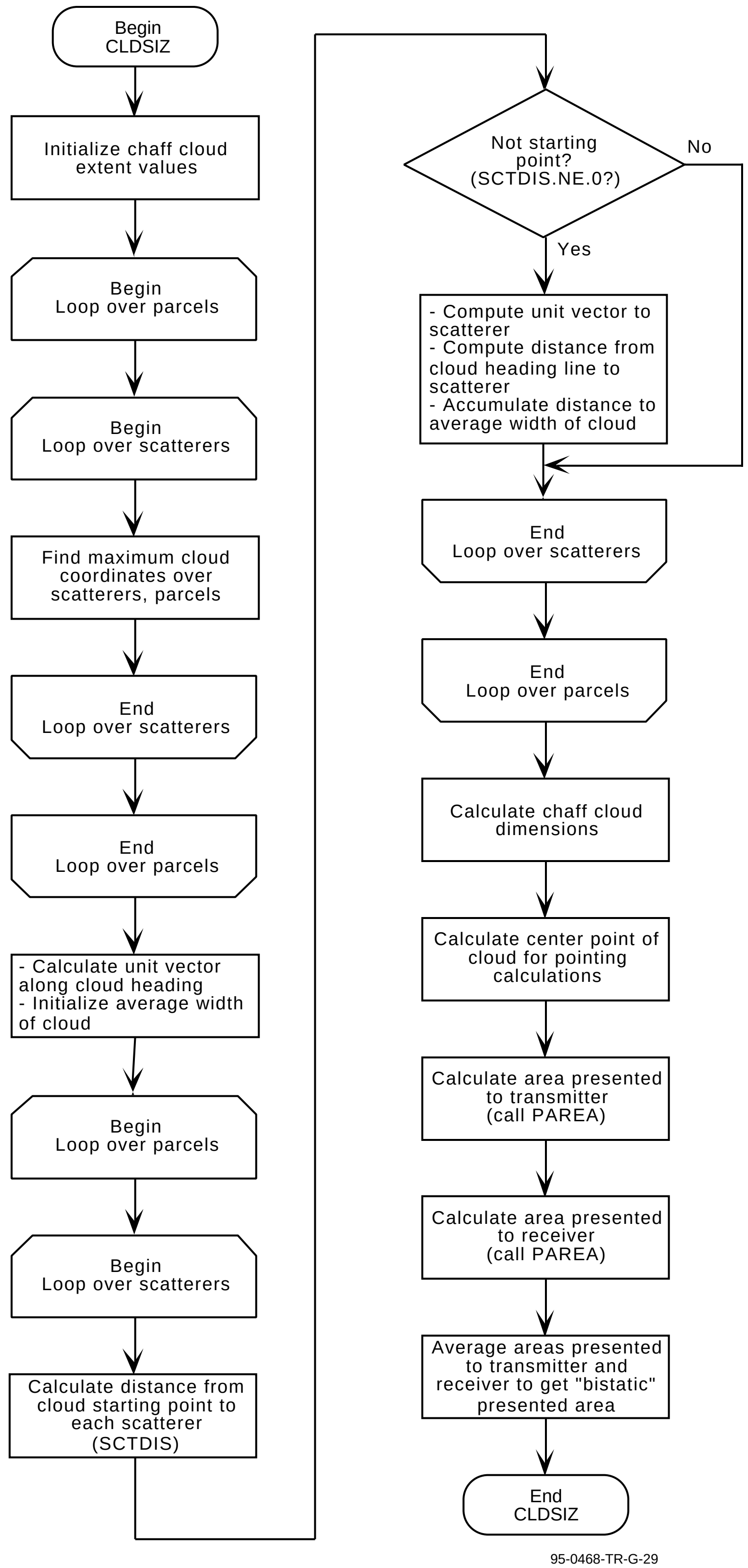

FIGURE 2.9-18. Functional Flow Diagram for Subroutine CLDSIZ.

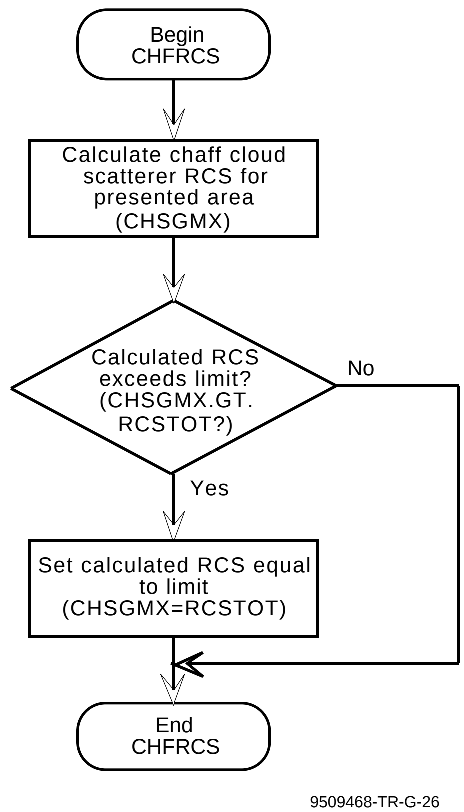

FIGURE 2.9-19. Functional Flow Diagram for Subroutine CHFRCS.

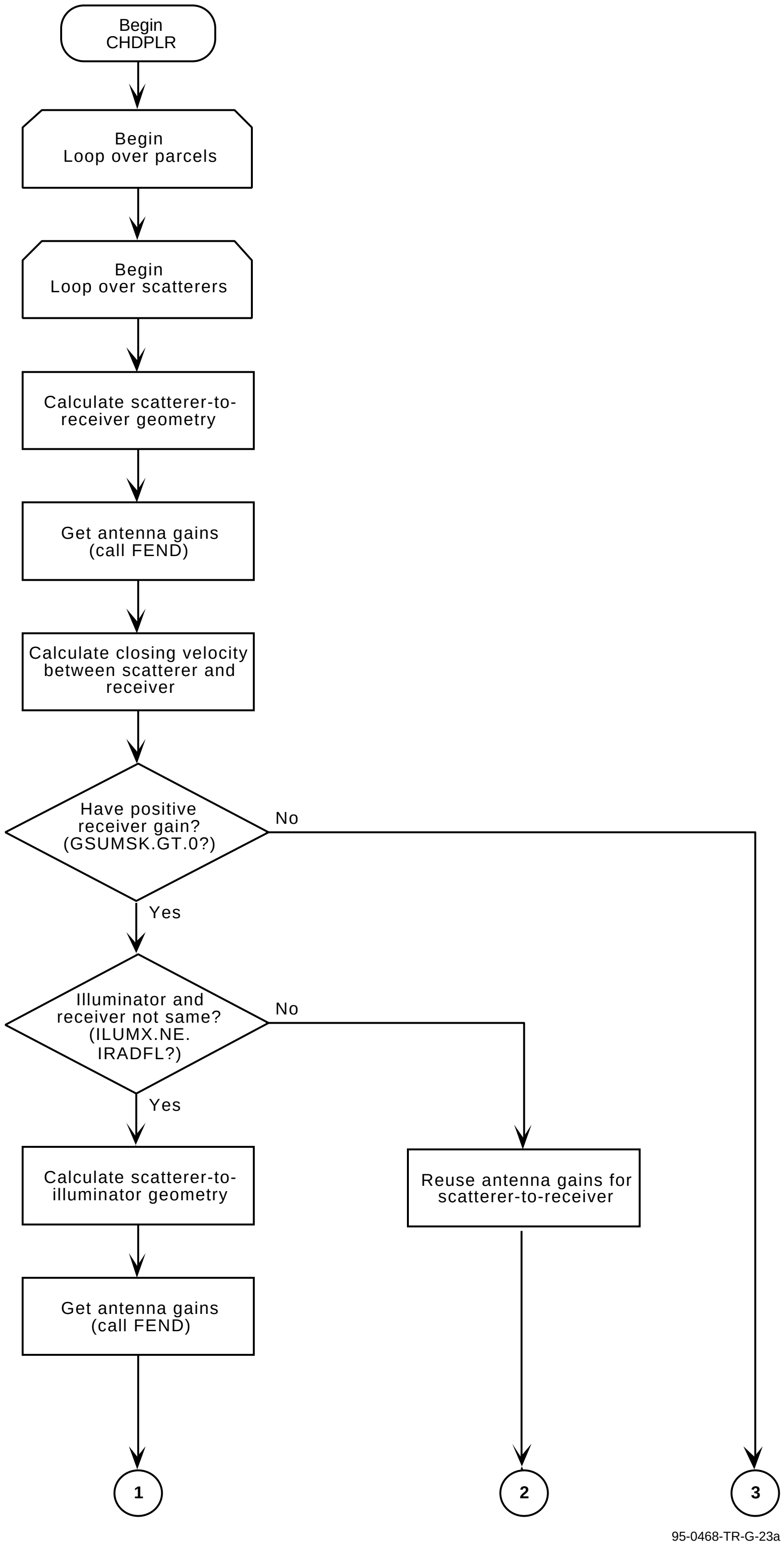

FIGURE 2.9-20. Functional Flow Diagram for Subroutine CHDPLR.

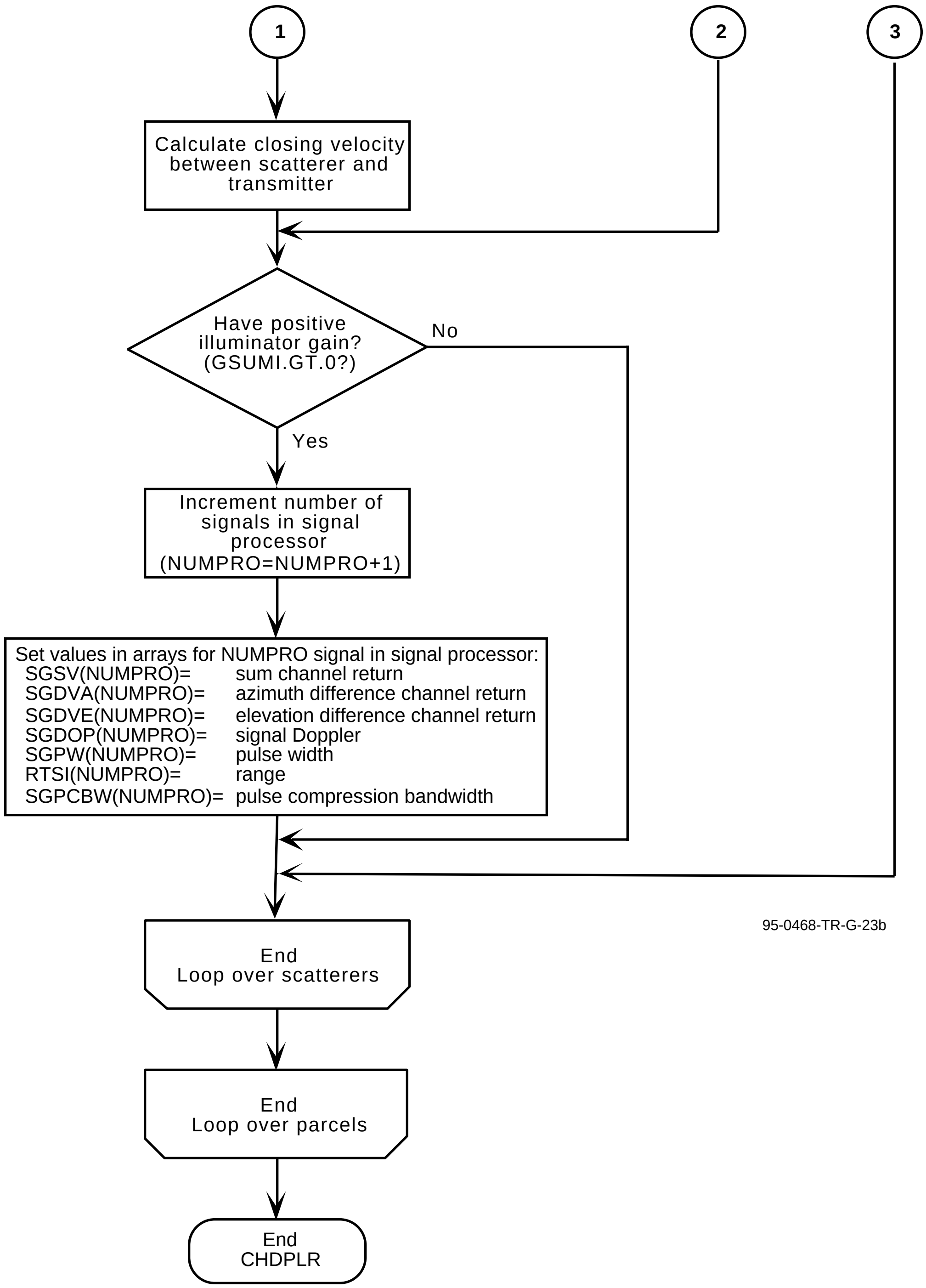

FIGURE 2.9-20. Functional Flow Diagram for Subroutine CHDPLR. (Contd.)

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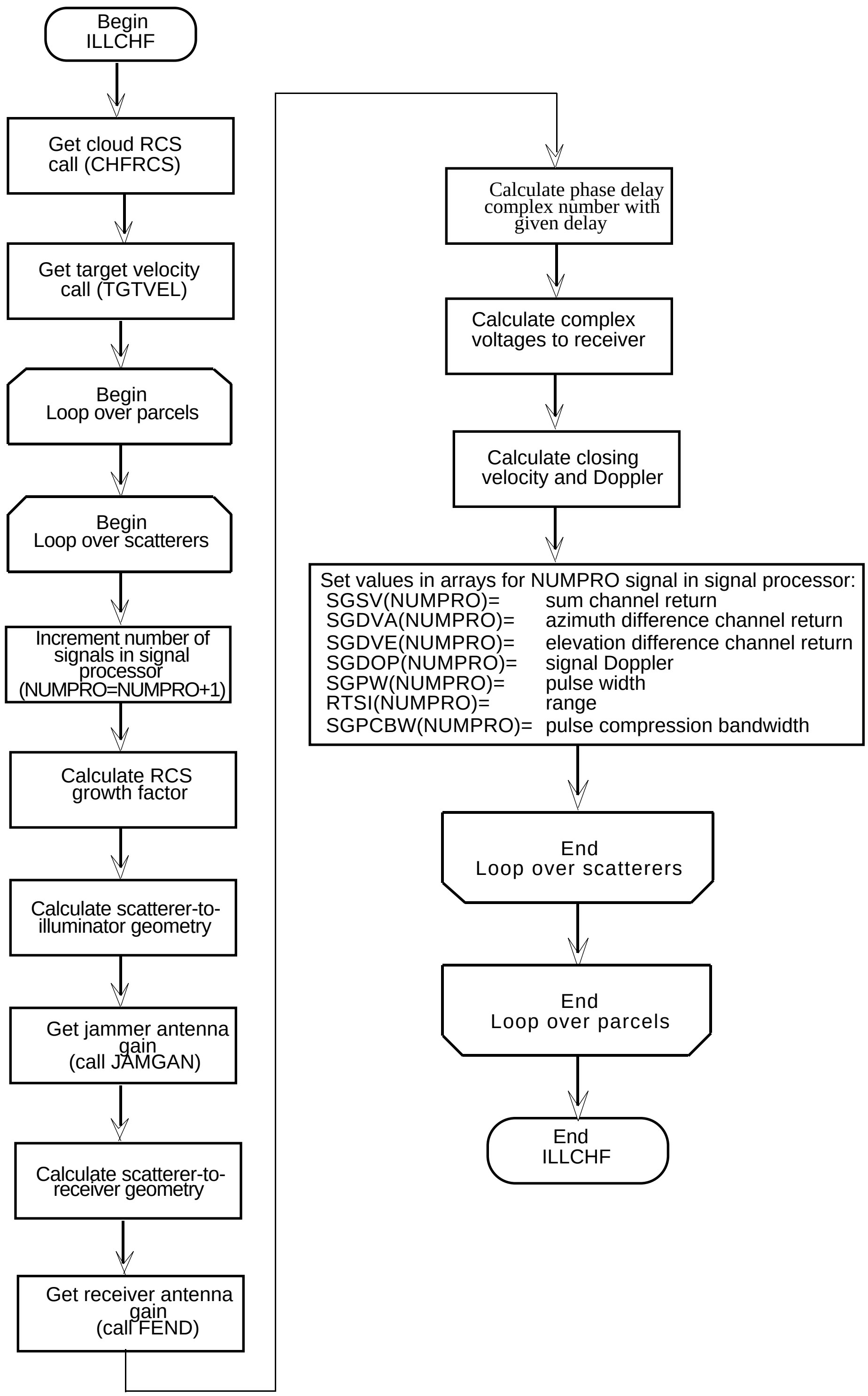

FIGURE 2.9-21. Functional Flow Diagram for Subroutine ILLCHF.

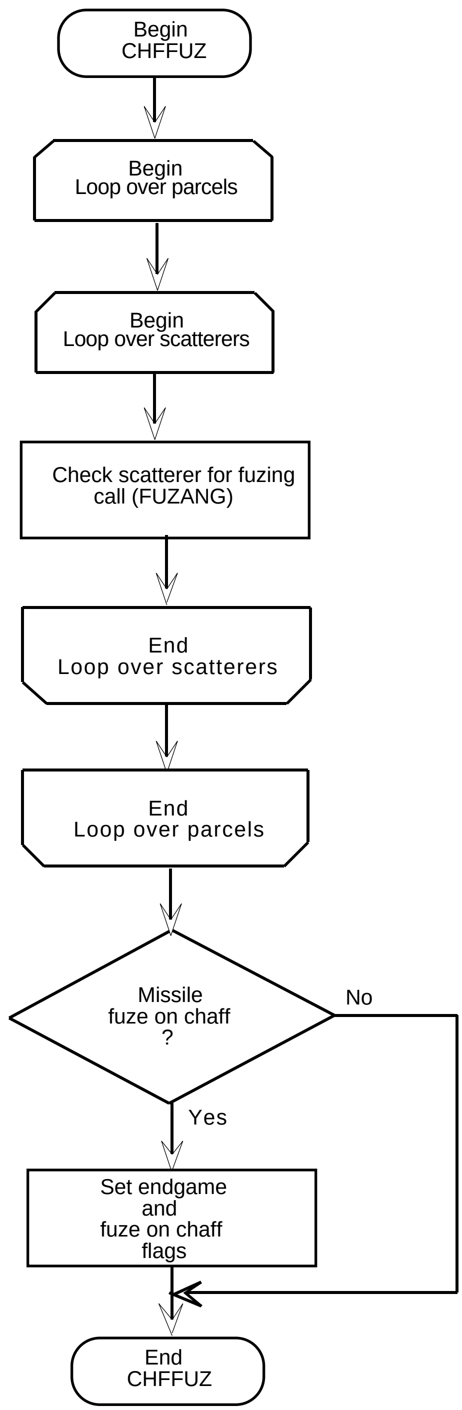

FIGURE 2.9-22. Functional Flow Diagram for Subroutine CHFFUZ.

ECM Deceptive Off-Board Inputs and Outputs

The model inputs that affect the ECM Deceptive Off-Board Functional Element are listed in Table 2.9-3.

TABLE 2.9-3. ECM Deceptive Off-Board Model Inputs.

Name	Source	Description
AMPROA(-)	Common ECMD	Array of flags indicating whether jammer amplitudes are relative or absolute. (=0, relative; otherwise, absolute; =2, case of repeater gain on power) Dimensioned NUMTEC (= 50).
ANSLW(-)	Common ECMD	Flag for whether the antenna is slewable. (=0, fixed; =1, slewable). (Real form) Dimensioned NUMANT (=10).
ANTPAZ(-)	Common ECMD	Array of jammer antenna pointing angles in azimuth. Dimensioned NUMANT (=10).
ANTPEL(-)	Common ECMD	Array of jammer antenna pointing angles in elevation. Dimensioned NUMANT (=10).
ANTXLO(-)	Common ECMD	X-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTYLO(-)	Common ECMD	Y-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
ANTZLO(-)	Common ECMD	Z-component of jammer antenna location on platform. Dimensioned NUMANT (=10).
CHFILL(-)	Common ECMD	Flags for illuminate chaff option. Dimensioned NUMTEC (=50).
CHRPT(-,-)	Common ECMD	Pointers to jammer characteristics tables. (Real form) Dimensioned NJCHAR (=6) by NUMTEC (=50).
CNTFRQ(-)	Common ECMD	Center frequency for wobbulation generation. Dimensioned NUMTEC (=50).
DLYROA(-)	Common ECMD	Array of flags indicating whether jammer time delays are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
DURTIM(-)	Common ECMD	Duration times for jammer techniques. Dimensioned NUMTEC (=50).
DUTCYL(-)	Common ECMD	Duty cycle for wobbulation generation. Dimensioned NUMTEC (=50).
ECMT(-)	Common ECMD	Workspace array in which jammer tables are kept; pointers locate the tables in ECMT. (Used in ECMINI only for towed decoy.) Dimensioned LECMT (=13757).
ECMT(-)	Common ECMD	Workspace array for jammer tables. Dimensioned NUMANT (=10).
FRQROA(-)	Common ECMD	Array of flags indicating whether jammer frequencies are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
OFFFRQ(-)	Common ECMD	Offset frequency for wobbulation generation. Dimensioned NUMTEC (=50).
PANT(-)	Common ECMD	Pointer to ATJ jammer antenna table. (Real form) Dimensioned NUMANT (=10).
PHSROA(-)	Common ECMD	Array of flags indicating whether jammer phases are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).

TABLE 2.9-3. ECM Deceptive Off-Board Model Inputs. (Contd.)

Name	Source	Description
PLSROA(-)	Common ECMD	Array of flags indicating whether jammer pulse widths are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
POLROA(-)	Common ECMD	Array of flags indicating whether jammer polarizations are relative or absolute. (=0, relative; otherwise, absolute) Dimensioned NUMTEC (= 50).
PWRMAX	Common ECMD	Maximum power for jammer.
RADCHF	Common ECMD	Flag indicating whether chaff is used.
RADJAM(-)	Common ECMD	Active list of radars. Dimensioned NUMTEC (=50).
RCVPAT(-)	Common ECMD	ECM receiver antenna table. Dimensioned LPATRN (=13757)
RMPTIM(-)	Common ECMD	Ramp time for wobbulation generation (time required for wobbulation sweep). Dimensioned NUMTEC (=50).
SPCWID(-)	Common ECMD	Noise jamming spectral width. Dimensioned NUMTEC (=50).
SWPTYP(-)	Common ECMD	Sweep type index for wobbulation generation. Dimensioned NUMTEC (=50).
TECAZB(-)	Common ECMD	Minimum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECAZF(-)	Common ECMD	Maximum azimuth of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECHQN	Common ECMD	Number of jammer techniques to be used.
TECMOD(-)	Common ECMD	Radar mode to apply jammer technique against. Dimensioned NUMTEC (=50).
TECRMB(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TECRMF(-)	Common ECMD	Minimum range of site with respect to target for jammer technique. Dimensioned NUMTEC (=50).
TIMEON(-)	Common ECMD	Beginning of time window for jamming by technique. Dimensioned NUMTEC (=50).
TIMOFF(-)	Common ECMD	Ending of time window for jamming by technique. Dimensioned NUMTEC (=50).
XMTPAT(-)	Common ECMD	Jammer transmitter antenna table. Dimensioned LPATRN (=13757).
XDCYTI	Common ECMD	Scenario time to deploy towed decoy.
XDCYTT	Common ECMD	Time to go to deploy towed decoy.
XDISMA	Common ECMD	Maximum distance between towed decoy and target.
XDPLRA	Common ECMD	Deployment rate for towed decoy.
XTDAZ	Common ECMD	Azimuth with respect to target for deployed towed decoy.
XTDEL	Common ECMD	Elevation with respect to target for deployed towed decoy.
XTDSIG	Common ECMD	Pointer to towed decoy signature table. (Real form)

The outputs of the ECM Deceptive Off-Board Functional Element are jam signals onthe signal bus, the count of signals onthe bus [NUMPRO] incremented for the added jam signals, and times and flags relating to jammer action; these are listed in Table 2.9-4.

TABLE 2.9-4. ECM Deceptive Off-Board Model Outputs.

Name	Source	Description
IDBUS(-)	Argument returned from BEMGRM	Array of signal ID values [signal bus].
NUMPRO	Argument returned from BEMGRM	Current number of signals on signal processor bus. Incremented from input value by number of jammer signals placed on signal bus.
RTSI(-)	Argument returned from BEMGRM	Array of ranges for signals [signal bus].
SGDOP(-)	Argument returned from BEMGRM	Array of signal Doppler shifts [signal bus].
SGDVA(-)	Argument returned from BEMGRM	Array of complex azimuth-differential channel signal voltages [signal bus.].
SGDVE(-)	Argument returned from BEMGRM	Array of complex elevation-differential channel signal voltages [signal bus.].
SGPCBW(-)	Argument returned from BEMGRM	Array of signal pulse compression bandwidths [signal bus].
SGPW(-)	Argument returned from BEMGRM	Array of signal pulse widths [signal bus].
SGSV(-)	Argument returned from BEMGRM	Array of complex sum channel signal voltages [signal bus.].
STRTED(-)	Common ECMV	Flags indicating that jammer techniques have started. Dimensioned NUMTEC (=50).
TIMMOD(-)	Common ECMV	Times for which system has been in operating modes. Dimensioned NUMMOD (=6).
TSTECH(-)	Common ECMV	Times at which jamming techniques started. Dimensioned NUMTEC (=50).

Inputs and outputs for the subroutines not covered in other FEs that are allocated to the implementation of the ECM Deceptive Off-Board functional element follow.

TABLE 2.9-5a. Functional Element: ECM Noise—Input Data.

Name	Location	Description
ANSLW(-)	Common ECMD	Flag for whether the antenna is slewable. (=0, fixed; =1, slewable). (Real form) Dimensioned NUMANT (=10).
CHRPT(-,-)	Common ECMD	Pointers to jammer characteristics tables. (Real form) Dimensioned NJCHAR (=6) by NUMTEC (=50).
CNTFRQ(-)	Common ECMD	Center frequency for wobbulation generation. Dimensioned NUMTEC (=50).
DUTCYL(-)	Common ECMD	Duty cycle for wobbulation generation. Dimensioned NUMTEC (=50).

TABLE 2.9-5a. Functional Element: ECM Noise—Input Data. (Contd.)

Name	Location	Description
ECMT(-)	Common ECMD	Workspace array in which jammer tables are kept; pointers locate the tables in ECMT. (Used in ECMINI only for towed decoy.) Dimensioned LECMT (=13757).
ISPS(5)	Common PROGVI	Fifth element of ISPS(-); here temporarily reset to 1 for input of ECM antenna pattern tables XMTPAT and RCVPAT, then immediately reset to original value. (No actual impact on ECM functionality.)
IWARN	PARAMETER (Include CONST)	Symbolic value for warning-level of error severity. (Initialized to 0.)
LPATRN	PARAMETER (Include ECMD)	Dimension for ECM antenna pattern table arrays, XMTPAT and RCVPAT. (Initialized to 13757.)
LUNLP	Common RUNVI	Logical unit number for “lineprinter” output.
NJCHAR	PARAMETER (Include PARAM)	Maximum number of jammer characteristics that can be used with each technique. (Initialized to 6.)
NUMANT	PARAMETER (Include PARAM)	Maximum number of ECM antennas that can be used. (Initialized to 10.)
NUMMOD	PARAMETER (Include ARYBND)	Maximum number of different operating beam modes. (Initialized to 6.)
NUMTEC	PARAMETER (Include PARAM)	Maximum number of ECM techniques that can be used. (Initialized to 50.)
OFFFRQ(-)	Common ECMD	Offset frequency for wobbulation generation. Dimensioned NUMTEC (=50).
PANT(-)	Common ECMD	Pointer to ATJ jammer antenna table. (Real form) Dimensioned NUMANT (=10).
RMPTIM(-)	Common ECMD	Ramp time for wobbulation generation (time required for wobbulation sweep). Dimensioned NUMTEC (=50).
SWPTYP(-)	Common ECMD	Sweep type index for wobbulation generation. Dimensioned NUMTEC (=50).
XDCYTI	Common ECMD	Scenario time to deploy towed decoy.
XDCYTT	Common ECMD	Time to go to deploy towed decoy.
XDISMA	Common ECMD	Maximum distance between towed decoy and target.
XDPLRA	Common ECMD	Deployment rate for towed decoy.
XTDAZ	Common ECMD	Azimuth with respect to target for deployed towed decoy.
XTDEL	Common ECMD	Elevation with respect to target for deployed towed decoy.
XTDSIG	Common ECMD	Pointer to towed decoy signature table. (Real form)

TABLE 2.9-5b. Functional Element: ECM Noise—Output Data.

Name	Location	Description
IDBUS(-)	Common SIGNLI (Include SIGNLS)	Array of signal ID values [signal bus]. Updated for jammer signals generated by ECM Noise functional element.
NUMPRO	Common SIGNLI (Include SIGNLS)	Current number of signals on signal processor bus. Updated for jammer signals generated by ECM Noise functional element.
RTSI(-)	Common SIGNLR (Include SIGNLS)	Array of ranges for signals [signal bus]. Updated for jammer signals generated by ECM Noise functional element.
SGDOP(-)	Common SIGNLR (Include SIGNLS)	Array of signal Doppler shifts [signal bus]. Updated for jammer signals generated by ECM Noise functional element.
SGDVA(-)	Common SIGNLC (Include SIGNLS)	Array of complex azimuth-differential channel signal voltages [signal bus.]. Updated for jammer signals generated by ECM Noise functional element.
SGDVE(-)	Common SIGNLC (Include SIGNLS)	Array of complex elevation-differential channel signal voltages [signal bus.]. Updated for jammer signals generated by ECM Noise functional element.
SGPCBW(-)	Common SIGNLR (Include SIGNLS)	Array of signal pulse compression bandwidths [signal bus]. Updated for jammer signals generated by ECM Noise functional element.
SGPW(-)	Common SIGNLR (Include SIGNLS)	Array of signal pulse widths [signal bus]. Updated for jammer signals generated by ECM Noise functional element.
SGSV(-)	Common SIGNLC (Include SIGNLS)	Array of complex sum channel signal voltages [signal bus.]. Updated for jammer signals generated by ECM Noise functional element.
STRTED(-)	Common ECMV	Flags indicating that jammer techniques have started. Updated for jammer signals generated by ECM Noise functional element.
TIMMOD(-)	Common ECMV	Times for which system has been in operating modes. Updated for jammer signals generated by ECM Noise functional element.
TSTECH(-)	Common ECMV	Times at which jamming techniques started. Updated for jammer signals generated by ECM Noise functional element.

TABLE 2.9-6. Subroutine I/O Table Cross Reference.

Subroutine	Input	Output
ECMINI	2.5-4a	2.5-4b
BEMGRM	2.5-5a	2.5-5b
BEMANT	2.5-6a	2.5-6b
BEMTVL	2.5-7a	2.5-7b
BEMSVL	2.5.8a	2.5-8b
BEMFVL	2.5-9a	2.5-9b
BEMSEM	2.5-10a	2.5-10b
BEMEXC	2.5-11a	2.5-11b
BEMNZ	2.5-12a	2.5-12b
BEMOUT	2.5-13a	2.5-13b
BEMSET	2.5-14a	2.5-14b

TABLE 2.9-7a. Subroutine TDEXC–Input Data.

Name	Source	Description
DFJMAZ	Return from SKNSIG	Azimuth channel voltage for jam signal (v).
DFJMEL	Return from SKNSIG	Elevation channel voltage for jam signal (v).
DOPJAM	Return from SKNSIG	Doppler for jam signal (Hz).
JAMINX	Argument	Index into jam signal array.
LTDASP	Common TDCY	Pointer into towed decoy signature table.
LTDROT	Common TDCY	Pointer into towed decoy signature table.
PCBWJM	Return from SKNSIG	Pulse compression bandwidth for jam signal.
PWJAM	Return from SKNSIG	Pulse width for jam signal.
RCS	Return from GETRCS	Radar cross-section of towed decoy.
RSJAM	Return from SKNSIG	Range for jam signal.
SUMJAM	Return from SKNSIG	Sum channel voltage for jam signal (v).
TDOUT	Common TDCY	Towed decoy deployed flag (0=not deployed, 1=deployed).
TDPHI	Return from TDROLL	Towed decoy roll angle (Euler angle of orientation phi) (radians).
TDPSI	Return from TDROLL	Towed decoy yaw angle (heading) (Euler angle of orientation psi) (radians).
TDSIG(-)	Common TDCY	Towed decoy signature data. Dimensioned MXTDSG (=1000).
TDTHET	Return from TDROLL	Towed decoy pitch angle (Euler angle of orientation theta) (radians).
TDX	Return from TDPOS	Towed decoy location , X coordinate, inertial coordinate system (m).
TDXDOT	Return from TDVEL	Towed decoy velocity, X component, inertial coordinate system (m/sec).
TDY	Return from TDPOS	Towed decoy location , Y coordinate, inertial coordinate system (m).
TDYDOT	Return from TDVEL	Towed decoy velocity, Y component, inertial coordinate system (m/sec).
TDZ	Return from TDPOS	Towed decoy location , Z coordinate, inertial coordinate system (m).
TDZDOT	Return from TDVEL	Towed decoy velocity, Z component, inertial coordinate system (m/sec).
TIMEG	Argument	Time for calculations.
XSJ	Return from SITPOS	Current site location, X coordinate (m).
XV	Argument	Victim location , X coordinate, inertial coordinate system (m).
XVDOT	Argument	Victim velocity , X component, inertial coordinate system (m).
YSJ	Return from SITPOS	Current site location, Y coordinate (m).
YV	Argument	Victim location , Y coordinate, inertial coordinate system (m).
YVDOT	Argument	Victim velocity , Y component, inertial coordinate system (m).
ZSJ	Return from SITPOS	Current site location, Z coordinate (m).
ZV	Argument	Victim location , Z coordinate, inertial coordinate system (m).
ZVDOT	Argument	Victim velocity , Z component, inertial coordinate system (m).

TABLE 2.9-7b. Subroutine TDEXC–Output Data.

Name	Source	Description
DFJMAZ	Argument	Azimuth channel voltage for jam signal (v).
DFJMEL	Argument	Elevation channel voltage for jam signal (v).
DOPJAM	Argument	Doppler for jam signal (Hz).
JAMINX	Argument	Index into jam signal array.
PCBWJM	Argument	Pulse compression bandwidth for jam signal.
PWJAM	Argument	Pulse width for jam signal.
RSJAM	Argument	Range for jam signal.
SUMJAM	Argument	Sum channel voltage for jam signal (v).

TABLE 2.9-8a. Subroutine SKNSIG–Input Data.

Name	Source	Description
DOPJAM	Argument	Doppler for jam signal (Hz).
GAIN	Return from FEND	Fuze antenna gain
GDFAZ	Return from FEND	Azimuth channel antenna gain for ground rada, seeker, or fuze.
GDFAZI	Return from FEND	Azimuth channel antenna gain for illuminator.
GDFEL	Return from FEND	Elevation channel antenna gain for ground rada, seeker, or fuze.
GDFELI	Return from FEND	Elevation channel antenna gain for illuminator.
GILL	Return from FEND	Sum channel gain for illuminator.
GRCVR	Return from FEND	sum channel gain for seeker.
GSUM	Return from FEND	Sum channel gain for ground radar.
PWR	Return from AFMPWR	Fuze transmitter power.
PWRTX	Common GRADAR	Transmitter average power.
PWTX	Common GRADAR	Transmitter pulse width.
TDRCS	Argument	Towed decoy RCS
TDXDOT	Argument	Towed decoy velocity, X component, inertial coordinate system.
TDYDOT	Argument	Towed decoy velocity, Y component, inertial coordinate system.
TDZDOT	Argument	Towed decoy velocity, Z component, inertial coordinate system.
WVL	Return from AFMWVL	Fuze walelength.
WVLTX	Common GRADAR	Transmitter wavelength
XLS	Return from AFMWVL	Fuze correction loss factor.
XLOSS	Common GRADAR	Transmitter correction loss factor.
XSTD	Argument	X separation site to towed decoy.
XVDOT	Argument	Victim X velocity.
XVTD	Argument	X separation towed decoy to site.
YSTD	Argument	Y separation site to towed decoy.
YVDOT	Argument	Victim Y velocity.
YVTD	Argument	Y separation towed decoy to site.
ZSTD	Argument	Z separation site to towed decoy.
ZVDOT	Argument	Victim Z velocity.
ZVTD	Argument	Z separation towed decoy to site.

TABLE 2.9-8b. Subroutine SKNSIG–Output Data.

Name	Source	Description
DFJMAZ	Argument	Azimuth channel voltage for jam signal (v).
DFJMEL	Argument	Elevation channel voltage for jam signal (v).
DOPJAM	Argument	Doppler for jam signal (Hz).
PCBWJM	Argument	Pulse compression bandwidth for jam signal.
PWJAM	Argument	Pulse width for jam signal.
RSJAM	Argument	Range for jam signal.
SUMJAM	Argument	Sum channel voltage for jam signal (v).

TABLE 2.9-9a. Subroutine TDDPLY–Input Data.

Name	Source	Description
AMISX	Return from MISXXX.MISPOS	Missile location, X coordinate, inertial coordinate system (m).
AMISXD	Return from MISXXX.MISVEL	Missile velocity, X component, inertial coordinate system (m).
AMISY	Return from MISXXX.MISPOS	Missile location, Y coordinate, inertial coordinate system (m).
AMISYD	Return from MISXXX.MISVEL	Missile velocity, Y component, inertial coordinate system (m).
AMISZ	Return from MISXXX.MISPOS	Missile location, Z coordinate, inertial coordinate system (m).
AMISZD	Return from MISXXX.MISVEL	Missile velocity, Z component, inertial coordinate system (m).
DCYTIM	Common TDCY	Scenario time to deploy towed decoy (sec).
DCYTTG	Common TDCY	Time to go to deploy towed decoy (sec).
TDOUT	Common TDCY	Towed decoy deployed flag (0=not deployed, 1=deployed).
TGTX	Return from TGTXXX.TGTPOS	Target location, X coordinate, inertial coordinate system (m).
TGTXD	Return from TGTXXX.TGTVEL	Target velocity, X component, inertial coordinate system (m/sec).
TGTY	Return from TGTXXX.TGTPOS	Target location, Y coordinate, inertial coordinate system (m).
TGTYD	Return from TGTXXX.TGTVEL	Target velocity, Y component, inertial coordinate system (m/sec).
TGTZ	Return from TGTXXX.TGTPOS	Target location, Z coordinate, inertial coordinate system (m).
TGTZD	Return from TGTXXX.TGTVEL	Target velocity, Z component, inertial coordinate system (m/sec).
TIMEG	Argument	Time for calculations.

TABLE 2.9-9b. Subroutine TDDPLY–Output Data.

Name	Source	Description
TDOUT	Common TDCY	Towed decoy deployed flag (0=not deployed, 1=deployed).
TIMDPL	Common TDCY	Time at which towed decoy was deployed (sec).

TABLE 2.9-10a. Subroutine TDPOS–Input Data.

Name	Source	Description
DISMAX	Common TDCY	Maximum distance from towed decoy to target (m).
DPLRAT	Common TDCY	Towed decoy deployment rate (m/sec).
KB2I	PARAMETER, Include CONST	Integer constant indicating body to inertial coordinate system transformation for GYRATE direction flag (=2).
TDFLOT	Common TDCY	Towed decoy follows target trajectory flag (0=no, 1=yes).
TDOUT	Common TDCY	Towed decoy deployed flag (0=not deployed, 1=deployed).
TDXMAX	Common TDCY	Maximum separation of towed decoy from target, X component, (m).
TDYMAX	Common TDCY	Maximum separation of towed decoy from target, Y component, (m).
TDZMAX	Common TDCY	Maximum separation of towed decoy from target, Z component, (m).
TGTPHI	Return from TGTXXX.TGTROL	Target roll angle (Euler angle of orientation phi) (radians).
TGTPSI	Return from TGTXXX.TGTROL	Target yaw angle (heading) (Euler angle of orientation psi) (radians).
TGTTHT	Return from TGTXXX.TGTROL	Target pitch angle (Euler angle of orientation theta) (radians).
TGTX	Return from TGTXXX.TGTPOS	Target location, X coordinate, inertial coordinate system (m).
TGTXD	Return from TGTXXX.TGTVEL	Target velocity, X component, inertial coordinate system (m/sec).
TGTY	Return from TGTXXX.TGTPOS	Target location, Y coordinate, inertial coordinate system (m).
TGTYD	Return from TGTXXX.TGTVEL	Target velocity, Y component, inertial coordinate system (m/sec).
TGTZ	Return from TGTXXX.TGTPOS	Target location, Z coordinate, inertial coordinate system (m).
TGTZD	Return from TGTXXX.TGTVEL	Target velocity, Z component, inertial coordinate system (m/sec).
TIMDPL	Common TDCY	Time at which towed decoy was deployed (sec).
TIMEG	Argument	Time for calculations.
XOUTI	Return from GYRATE	X component of vector from towed decoy to target, inertial coordinate system (m).
YOUTI	Return from GYRATE	Y component of vector from towed decoy to target, inertial coordinate system (m).
ZOUTI	Return from GYRATE	Z component of vector from towed decoy to target, inertial coordinate system (m).

TABLE 2.9-10b. Subroutine TDPOS–Output Data.

Name	Source	Description
TDRNG	Common TDCY	Slant range from towed decoy to target (m).
TDX	Argument	Towed decoy location , X coordinate, inertial coordinate system (m).
TDY	Argument	Towed decoy location , Y coordinate, inertial coordinate system (m).
TDZ	Argument	Towed decoy location , Z coordinate, inertial coordinate system (m).

TABLE 2.9-11a. Subroutine TDVEL–Input Data.

Name	Source	Description
DISMAX	Common TDCY	Maximum distance from towed decoy to target (m).
DPLRAT	Common TDCY	Towed decoy deployment rate (m/sec).
KB2I	PARAMETER, Include CONST	Integer constant indicating body to inertial coordinate system transformation for GYRATE direction flag (=2).
TDFLOT	Common TDCY	Towed decoy follows target trajectory flag (0=no, 1=yes).
TDOUT	Common TDCY	Towed decoy deployed flag (0=not deployed, 1=deployed).
TDRNG	Common TDCY	Slant range from towed decoy to target (m).
TDXDOT	Return from TGTXXX.TGTVEL	Towed decoy velocity, X component, inertial coordinate system (m/sec).
TDXMAX	Common TDCY	Maximum separation of towed decoy from target, X component, (m).
TDYDOT	Return from TGTXXX.TGTVEL	Towed decoy velocity, Y component, inertial coordinate system (m/sec).
TDYMAX	Common TDCY	Maximum separation of towed decoy from target, Y component, (m).
TDZDOT	Return from TGTXXX.TGTVEL	Towed decoy velocity, Z component, inertial coordinate system (m/sec).
TDZMAX	Common TDCY	Maximum separation of towed decoy from target, Z component, (m).
TGTPHI	Return from TGTXXX.TGTROL	Target roll angle (Euler angle of orientation phi) (radians).
TGTPSI	Return from TGTXXX.TGTROL	Target yaw angle (heading) (Euler angle of orientation psi) (radians).
TGTTHT	Return from TGTXXX.TGTROL	Target pitch angle (Euler angle of orientation theta) (radians).
TGTXD	Return from TGTXXX.TGTVEL	Target velocity, X component, inertial coordinate system (m/sec).
TGTYD	Return from TGTXXX.TGTVEL	Target velocity, Y component, inertial coordinate system (m/sec).
TGTZD	Return from TGTXXX.TGTVEL	Target velocity, Z component, inertial coordinate system (m/sec).
TIMEG	Argument	Time for calculations.
XD	Return from GYRATE	Towed decoy deployment velocity, X component, inertial coordinate system (m/sec).
YD	Return from GYRATE	Towed decoy deployment velocity, Y component, inertial coordinate system (m/sec).
ZD	Return from GYRATE	Towed decoy deployment velocity, Z component, inertial coordinate system (m/sec).

TABLE 2.9-11b. Subroutine TDVEL–Output Data.

Name	Source	Description
TDXDOT	Argument	Towed decoy velocity, X component, inertial coordinate system (m/sec).
TDYDOT	Argument	Towed decoy velocity, Y component, inertial coordinate system (m/sec).
TDZDOT	Argument	Towed decoy velocity, Z component, inertial coordinate system (m/sec).

TABLE 2.9-12a. Subroutine TDROLL–Input Data.

Name	Source	Description
TDFLOT	Common TDCY	Towed decoy follows target trajectory flag (0=no, 1=yes).
TDPHI	Return from TGTXXX.TGTROL	Towed decoy roll angle (Euler angle of orientation phi) (radians).
TDPSI	Return from TGTXXX.TGTROL	Towed decoy yaw angle (heading) (Euler angle of orientation psi) (radians).
TDRNG	Common TDCY	Slant range from towed decoy to target (m).
TDTHET	Return from TGTXXX.TGTROL	Towed decoy pitch angle (Euler angle of orientation theta) (radians).
TGTXD	Return from TGTXXX.TGTVEL	Target velocity, X component, inertial coordinate system (m/sec).
TGTYD	Return from TGTXXX.TGTVEL	Target velocity, Y component, inertial coordinate system (m/sec).
TGTZD	Return from TGTXXX.TGTVEL	Target velocity, Z component, inertial coordinate system (m/sec).
TIMEG	Argument	Time for calculations.

TABLE 2.9-12b. Subroutine TDROLL–Output Data.

Name	Source	Description
TDPHI	Argument	Towed decoy roll angle (Euler angle of orientation phi) (radians).
TDPSI	Argument	Towed decoy yaw angle (heading) (Euler angle of orientation psi) (radians).
TDTHET	Argument	Towed decoy pitch angle (Euler angle of orientation theta) (radians).

TABLE 2.9-13a. Subroutine CHFEXC–Input Data.

Name	Source	Description
CCCL	Common ECMD	Characteristic length of conical cylindrical cloud (m).
CHFAZB(-)	Common ECMD	Minimum site azimuth in aircraft system for turn-on. Dimensioned MXCHAF (=10).
CHFAZF(-)	Common ECMD	Maximum site azimuth in aircraft system for turn-on. Dimensioned MXCHAF (=10).
CHFMOD(-)	Common ECMD	Array of device modes for turn-on. Dimensioned MXCHAF (=10).
CHFRMB(-)	Common ECMD	Minimum aircraft-to-site range for turn-on. Dimensioned MXCHAF (=10).

TABLE 2.9-13a. Subroutine CHFEXC–Input Data. (Contd.)

Name	Source	Description
CHFRMF(-)	Common ECMD	Maximum aircraft-to-site range for turn-on. Dimensioned MXCHAF (=10).
DPDEL	Common ECMD	Minimum time interval for dropping poet (sec).
DTCHF	Common ECMD	Dispensal rate of chaff from rocket.
IACQR	PARAMETER Include ARYBND	Integer constant indicating acquisition radar type for IRADFL radar type flag (=1).
ILUMR	PARAMETER Include ARYBND	Integer constant indicating illuminator radar type for IRADFL radar type flag (=4).
ISEKR	PARAMETER Include ARYBND	Integer constant indicating seeker radar type for IRADFL radar type flag (=3).
ITRKR	PARAMETER Include ARYBND	Integer constant indicating tracker radar type for IRADFL radar type flag (=2).
JCHFRC(-)	Common ECMI	Flags indicating whether chaff is being used against radar types. Dimensioned 4.
NCHAFM	Common ECMI	Number of chaff drop modes.
PARC	Common ECMD	Maximum number of five scatterer parcels in chaff.
RTM	Return from RELXXX.RELROL	Range from target to missile (m).
RTMDOT	Return from RELXXX.RELROL	Range rate, target to missile (m/sec).
SCHAFF(-)	Common ECMD	Time for last chaff drop (sec). Dimensioned MXCHAF (=10).
SITR(-)	Return from SITXXX.SITPOS	Current site location vector (m). Dimensioned 3. Vector elements are X, Y, and Z coordinates, respectively.
TCHAFF(-)	Common ECMD	Time for first chaff drop (sec). Dimensioned MXCHAF (=10).
TGTO(-)	Return from TGTXXX.TGTRO L	Target orientation angles (radians). Dimensioned 3. Vector elements are Euler angles of psi, theta, and phi, respectively.
TGTR(-)	Return from TGTXXX.TGTPOS	Target location vector (m). Dimensioned 3. Vector elements are X, Y, and Z coordinates, respectively.
TIME	Argument	Time for calculations.
WVLTX(-)	Common GRADAR	Wavelength of ground radar transmitter (m).

TABLE 2.9-13b. Subroutine CHFEXC–Output Data.

Name	Source	Description
ICHAFF	Common ECMI	Initialization flag for chaff.
JCHFRC(-)	Common ECMI	Flags indicating whether chaff is being used against radar types. Dimensioned 4.
TI	Common ECCHAF	Time of first parcel drop (sec).

TABLE 2.9-14a. Subroutine CHAFFI–Input Data.

Name	Source	Description
CHAFSG	Return from TLU	Chaff cloud RCS (m2).
CHBLMT(-)	Common ECMD	Chaff bloom times for frequencies (sec). Dimensioned MAXCRC (=20).
CHFTPS	Common ECMD	Number of chaff dipole types in chaff cloud.

TABLE 2.9-14a. Subroutine CHAFFI–Input Data. (Contd.)

Name	Source	Description
CHRCST(-)	Common ECMD	Chaff cloud RCS values for radar frequencies (m2). Dimensioned MAXCRC (=20).
DIPLG(-)	Common ECMD	Length of chaff dipole for each type. Dimensioned MAXCTP (=9).
DIPOLN(-)	Common ECMD	Number of chaff dipoles for each type. Dimensioned MAXCTP (=9).
IRADFL	Argument	Radar type indicator (1=acquisition, 2=tracker, 3=seeker, 4=illuminator).
MXCHAF	PARAMETER Include ECMD	Maximum number of chaff drop modes (=10).
SCHAFF(-)	Common ECMD	Time for last chaff drop (sec). Dimensioned MXCHAF (=10).
SPDLGT	PARAMETER Include CONST	Speed of light (m/sec).
TCHAFF(-)	Common ECMD	Time for first chaff drop (sec). Dimensioned MXCHAF (=10).
WVL	Argument	Wavelength (m).

TABLE 2.9-14b. Subroutine CHAFFI–Output Data.

Name	Source	Description
DMAX	Common ECCHAF	Characteristic diameter of scatterers in parcel at time TAUD (m).
DSEP	Common ECCHAF	Separation distance from aircraft to point of initial chaff dispensing (m).
GCCH	Common ECCHAF	Main constant deceleration rate of chaff scatterer in longitudinal direction (m/sec2).
NCHAFM	Common ECMI	Number of chaff drop modes.
SIGTY(-,-)	Common ECCHAF	Sigma for a particular type of chaff. Dimensioned 10, MRADFL (=4).
SIGVL	Common ECCHAF	Standard deviation of chaff cloud scatterer velocity in long direction (m/sec).
SIGVR	Common ECCHAF	Standard deviation of chaff cloud scatterer velocity in radial direction (m/sec).
TAUD	Common ECCHAF	Time constant for chaff cylinder diameter growth.
TAURCS	Common ECCHAF	Chaff bloom time (sec).
TAUVL	Common ECCHAF	Time constant for random contribution to chaff cloud scatterer velocity in long direction (m/sec).
TAUVR	Common ECCHAF	Time constant for random contribution to chaff cloud scatterer velocity in radial direction (m/sec).
VFCH	Common ECCHAF	Mean fall velocity of chaff cloud dipoles (m/sec).
VWIND(-)	Common ECCHAF	Mean wind velocity vector (m/sec). Dimensioned 3. Vector elements are X, Y, and Z components, respectively.

TABLE 2.9-15a. Subroutine CHAFCI–Input Data.

Name	Source	Description
CCCL	Common ECMD	Characteristic length of conical cylindrical cloud (m).
DTCHF	Common ECMD	Dispensal rate of chaff from rocket.
PARC	Common ECMD	Maximum number of five scatterer parcels in chaff.
TI	Common ECCHAF	Time of first parcel drop (sec).
TIME	Argument	Time for calculations.

TABLE 2.9-15a. Subroutine CHAFCI–Input Data. (Contd.)

Name	Source	Description
XTDOTL	Return from TGTXXX.TGTVEL	Target velocity, X component, inertial coordinate system (m/sec).
XTL	Return from TGTXXX.TGTPOS	Target location, X coordinate, inertial coordinate system (m).
YTDOTL	Return from TGTXXX.TGTVEL	Target velocity, Y component, inertial coordinate system (m/sec).
YTL	Return from TGTXXX.TGTPOS	Target location, Y coordinate, inertial coordinate system (m).
ZTDOTL	Return from TGTXXX.TGTVEL	Target velocity, Z component, inertial coordinate system (m/sec).
ZTL	Return from TGTXXX.TGTPOS	Target location, Z coordinate, inertial coordinate system (m).

TABLE 2.9-15b. Subroutine CHAFCI–Output Data.

Name	Source	Description
ITSTOP(-)	Common ECMI	Flags indicating zero velocity for n-th parcel. Dimensioned 30.
RATI(-)	Common ECCHAF	Position vector of dispensing aircraft at time of first parcel drop, with respect to the current radar site position (m). Dimensioned 3. Vector elements are X, Y, and Z coordinates, respectively.
TIN(-)	Common ECCHAF	Drop times of parcels (sec). Dimensioned 30.
VATI	Common ECCHAF	Velocity (speed) of plane at time of first parcel drop (m/sec).
XSCT(-,-)	Common ECCHAF	X position of scatterers. Dimensioned 30, 5.
XSCTDT(-,-)	Common ECCHAF	Scatterer velocities in X direction. Dimensioned 30, 5.
XSTAR(-,-)	Common ECCHAF	X star scatterer position. Dimensioned 30, 5.
XSTDOT(-,-)	Common ECCHAF	X star scatterer velocity. Dimensioned 30, 5.
YSCT(-,-)	Common ECCHAF	Y position of scatterers. Dimensioned 30, 5.
YSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Y direction. Dimensioned 30, 5.
YSTAR(-,-)	Common ECCHAF	Y star scatterer position. Dimensioned 30, 5.
YSTDOT(-,-)	Common ECCHAF	Y star scatterer velocity. Dimensioned 30, 5.
ZSCT(-,-)	Common ECCHAF	Z position of scatterers. Dimensioned 30, 5.
ZSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Z direction. Dimensioned 30, 5.
ZSTAR(-,-)	Common ECCHAF	Z star scatterer position. Dimensioned 30, 5.
ZSTDOT(-,-)	Common ECCHAF	Z star scatterer velocity. Dimensioned 30, 5.

TABLE 2.9-16a. Subroutine CHFCLD–Input Data.

Name	Source	Description
DMAX	Common ECCHAF	Characteristic diameter of scatterers in parcel at time TAUD (m).
DPDEL	Common ECMD	Minimum time interval for dropping poet (sec).
DSEP	Common ECCHAF	Separation distance from aircraft to point of initial chaff dispensing (m).
DT	Common SIMVR	Step size (sec).
GCCH	Common ECCHAF	Main constant deceleration rate of chaff scatterer in longitudinal direction (m/sec2).
ICHAFF	Common ECMI	Initialization flag for chaff.

TABLE 2.9-16a. Subroutine CHFCLD–Input Data. (Contd.)

Name	Source	Description
PARC	Common ECMD	Maximum number of five scatterer parcels in chaff.
PHIT	Return from TGTROL	Target roll angle (Euler angle of orientation phi) (radians).
PIX2	PARAMETER Include CONST	Pi multiplied by 2.
PSIT	Return from TGTROL	Target yaw angle (heading) (Euler angle of orientation psi) (radians).
RATI(-)	Common ECCHAF	Position vector of dispensing aircraft at time of first parcel drop, with respect to the current radar site position (m). Dimensioned 3. Vector elements are X, Y, and Z coordinates, respectively.
SIGVL	Common ECCHAF	Standard deviation of chaff cloud scatterer velocity in long direction (m/sec).
SIGVR	Common ECCHAF	Standard deviation of chaff cloud scatterer velocity in radial direction (m/sec).
TAUD	Common ECCHAF	Time constant for chaff cylinder diameter growth.
TAUVL	Common ECCHAF	Time constant for random contribution to chaff cloud scatterer velocity in long direction (m/sec).
TAUVR	Common ECCHAF	Time constant for random contribution to chaff cloud scatterer velocity in radial direction (m/sec).
THETAT	Return from TGTROL	Target pitch angle (Euler angle of orientation theta) (radians).
TI	Common ECCHAF	Time of first parcel drop (sec).
TIME	Argument	Time for calculations.
TIN(-)	Common ECCHAF	Drop times of parcels (sec). Dimensioned 30.
VATI	Common ECCHAF	Velocity (speed) of plane at time of first parcel drop (m/sec).
VFCH	Common ECCHAF	Mean fall velocity of chaff cloud dipoles (m/sec).
VWIND(-)	Common ECCHAF	Mean wind velocity vector (m/sec). Dimensioned 3. Vector elements are X, Y, and Z components, respectively.

TABLE 2.9-16b. Subroutine CHFCLD–Output Data.

Name	Source	Description
EPSIL(-,-)	Common ECCHAF	Random number generated from RND(ISEED). Dimensioned 30, 16.
ICHAFF	Common ECMI	Initialization flag for chaff.
ITSTOP(-)	Common ECMI	Flags indicating zero velocity for n-th parcel. Dimensioned 30.
JEVNT	Common SIMVI	Jammer event print flag.
KPARC	Common ECMI	Actual number of parcels expended.
TI	Common ECCHAF	Time of first parcel drop (sec).
VC1(-)	Common ECCHAF	Expansion velocity in radial velocity. Dimensioned 30.
VC2(-)	Common ECCHAF	Scatterer diameter expansion velocity. Dimensioned 30.
VC3(-)	Common ECCHAF	Expansion velocity in longitudinal velocity. Dimensioned 30.
XSCT(-,-)	Common ECCHAF	X position of scatterers. Dimensioned 30, 5.
XSCTDT(-,-)	Common ECCHAF	Scatterer velocities in X direction. Dimensioned 30, 5.
XSTAR(-,-)	Common ECCHAF	X star scatterer position. Dimensioned 30, 5.
XSTDOT(-,-)	Common ECCHAF	X star scatterer velocity. Dimensioned 30, 5.
YSCT(-,-)	Common ECCHAF	Y position of scatterers. Dimensioned 30, 5.
YSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Y direction. Dimensioned 30, 5.
YSTAR(-,-)	Common ECCHAF	Y star scatterer position. Dimensioned 30, 5.

TABLE 2.9-16b. Subroutine CHFCLD–Output Data. (Contd.)

Name	Source	Description
YSTBAR(-)	Common ECCHAF	Y star mean position for n-th parcel. Dimensioned 30.
YSTBRD(-)	Common ECCHAF	Y star mean velocity for n-th parcel. Dimensioned 30.
YSTDOT(-,-)	Common ECCHAF	Y star scatterer velocity. Dimensioned 30, 5.
ZSCT(-,-)	Common ECCHAF	Z position of scatterers. Dimensioned 30, 5.
ZSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Z direction. Dimensioned 30, 5.
ZSTAR(-,-)	Common ECCHAF	Z star scatterer position. Dimensioned 30, 5.
ZSTDOT(-,-)	Common ECCHAF	Z star scatterer velocity. Dimensioned 30, 5.

TABLE 2.9-17a. Subroutine CHDPLR–Input Data.

Name	Source	Description
DFAZI	Return from FEND	Illuminator azimuth channel antenna gain.
DFAZSK	Return from FEND	Receiver azimuth channel antenna gain.
DFELI	Return from FEND	Illuminator elevation channel antenna gain.
DFELSK	Return from FEND	Receiver elevation channel antenna gain.
GSUMI	Return from FEND	Illuminator sum channel antenna gain.
GSUMSK	Return from FEND	Receiver sum channel antenna gain.
ILUMX	Argument	Pointer to illuminator radar variables.
IRADFL	Argument	Radar type indicator (1=acquisition, 2=tracker, 3=seeker, 4=illuminator).
KPARC	Argument	Actual number of chaff parcels expended.
NUMPRO	Argument	Number of signals in signal processor.
PCBW	Argument	Pulse compression bandwidth.
PWRTX	Argument	Transmitter power (w).
PWTX	Argument	Transmitter pulse width.
RCSCHF	Argument	Chaff cloud RCS (m2).
RCV(-)	Argument	Receiver position vector. Dimensioned 3.
RCVD(-)	Argument	Receiver velocity vector. Dimensioned 3.
TAURCS	Common ECCHAF	Chaff bloom time (sec).
TIMEB	Argument	Time for calculations.
TIN(-)	Common ECCHAF	Drop times of parcels (sec). Dimensioned 30.
WVLTX	Argument	Wavelength of radar transmitter (m).
XLOSS	Argument	Receiver loss factor.
XMT(-)	Argument	Transmitter position vector. Dimensioned 3.
XMTD(-)	Argument	Transmitter velocity vector. Dimensioned 3.
XSCT(-,-)	Common ECCHAF	X position of chaff cloud scatterers. Dimensioned 30, 5.
XSCTDT(-,-)	Common ECCHAF	Scatterer velocities in X direction. Dimensioned 30, 5.
YSCT(-,-)	Common ECCHAF	Y position of chaff cloud scatterers. Dimensioned 30, 5.
YSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Y direction. Dimensioned 30, 5.
ZSCT(-,-)	Common ECCHAF	Z position of chaff cloud scatterers. Dimensioned 30, 5.
ZSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Z direction. Dimensioned 30, 5.

TABLE 2.9-17b. Subroutine CHDPLR–Output Data.

Name	Source	Description
NUMPRO	Argument	Number of signals in signal processor.
RTSI(-)	Argument	Ranges.
SGDOP(-)	Argument	Signal Doppler shifts.
SGDVA(-)	Argument	Azimuth difference channel voltages.
SGDVE(-)	Argument	Elevation difference channel voltages.
SGPCBW(-)	Argument	Pulse compression bandwidths.
SGPW(-)	Argument	Pulse widths of signals.
SGSV(-)	Argument	Sum channel voltages.

TABLE 2.9-18a. Subroutine ILLCHF–Input Data.

Name	Source	Description
ANTX	Argument	Jamming antenna x position
ANTXD	Return from TGTVEL	Jamming antenna x velocity
ANTY	Argument	Jamming antenna y position
ANTYD	Return from TGTVEL	Jamming antenna y velocity
ANTZ	Argument	Jamming antenna z position
ANTZD	Return from TGTVEL	Jamming antenna z velocity
AREAFT	Argument	Chaff cloud cross section area view from front
AREASK	Argument	Chaff cloud cross section area viewed from receiver
CRCS	Return from CHFRCS	Chaff cloud RCS (m2).
DFAZSK	Return from FEND	Receiver azimuth channel antenna gain.
DFELSK	Return from FEND	Receiver elevation channel antenna gain.
GSUMI	Return from JAMGAN	Illuminator sum channel antenna gain.
GSUMSK	Return from FEND	Receiver sum channel antenna gain.
DOPPLER	Argument	Jamming Doppler offset
IANTEN	Argument	Jamming antenna selected flag
KPARC	Argument	Actual number of chaff parcels expended.
NUMPRO	Argument	Number of signals in signal processor.
PHASE	Argument	Jamming signal phase offset
POWER	Argument	Transmitter power (w).
PWIDTH	Argument	Transmitter pulse width.
SIGTY	Common ECCHAF	Maximum scatterer RCS for a dispersed cloud
TAURCS	Common ECCHAF	Chaff bloom time (sec).
TDEL	Argument	Jamming signal time delay.
TIMEB	Argument	Time for calculations.
TIN(-)	Common ECCHAF	Drop times of parcels (sec). Dimensioned 30.
WVLTX	Argument	Wavelength of radar transmitter (m).
XLOSS	Argument	Receiver loss factor.
XSCT(-,-)	Common ECCHAF	X position of chaff cloud scatterers. Dimensioned 30, 5.
XSCTDT(-,-)	Common ECCHAF	Scatterer velocities in X direction. Dimensioned 30, 5.
XV	Argument	Victim radar x position
XVDOT	Argument	Victim radar x velocity

TABLE 2.9-18a. Subroutine ILLCHF–Input Data. (Contd.)

Name	Source	Description
YSCT(-,-)	Common ECCHAF	Y position of chaff cloud scatterers. Dimensioned 30, 5.
YSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Y direction. Dimensioned 30, 5.
YV	Argument	Victim radar y position
YVDOT	Argument	Victim radar y velocity
ZSCT(-,-)	Common ECCHAF	Z position of chaff cloud scatterers. Dimensioned 30, 5.
ZSCTDT(-,-)	Common ECCHAF	Scatterer velocities in Z direction. Dimensioned 30, 5.
ZV	Argument	Victim radar z position
ZVDOT	Argument	Victim radar z velocity

TABLE 2.9-18b. Subroutine ILLCHF–Output Data.

Name	Source	Description
NUMPRO	Argument	Number of signals in signal processor.
RTSI(-)	Argument	Ranges.
SGDOP(-)	Argument	Signal Doppler shifts.
SGDVA(-)	Argument	Azimuth difference channel voltages.
SGDVE(-)	Argument	Elevation difference channel voltages.
SGPCBW(-)	Argument	Pulse compression bandwidths.
SGPW(-)	Argument	Pulse widths of signals.
SGSV(-)	Argument	Sum channel voltages.

TABLE 2.9-19a. Subroutine CHFRCS–Input Data.

Name	Source	Description
AREAP	Argument	Presented area for which RCS is to be calculated.
KPARC	Argument	Actual number of chaff parcels expended.
RCSTOT	Argument	RCS for dispersed chaff cloud viewed broadside (m2).

TABLE 2.9-19b. Subroutine CHFRCS–Output Data.

Name	Source	Description
CHSGMX	Argument	Chaff cloud scatterer RCS for presented area.

TABLE 2.9-20a. Subroutine CHFSIG–Input Data.

Name	Source	Description
AREAFT	Argument, Return from CLDSIZ	Chaff cloud cross sectional area as seen from the front (m2).
AREAP	Return from CLDSIZ	Bistatic chaff cloud cross sectional area (m2).
CRCS	Return from CHFRCS	Cloud RCS as seen by the receiver (m2).

TABLE 2.9-20a. Subroutine CHFSIG–Input Data. (Contd.)

Name	Source	Description
IACQR	PARAMETER Include ARYBND	Integer constant indicating acquisition radar type for IRADFL radar type flag (=1).
ILUMR	PARAMETER Include ARYBND	Integer constant indicating illuminator radar type for IRADFL radar type flag (=4).
IRADFL	Argument	Radar type indicator.
ITRKR	PARAMETER Include ARYBND	Integer constant indicating tracker radar type for IRADFL radar type flag (=2).
KPARC	Common ECMI	Actual number of parcels expended.
NUMPRO	Argument	Number of signals in signal processor.
PCBW(-)	Common GRADAR	Pulse compression bandwidth.
PWRTX	Common GRADAR	Transmitter power (w).
PWTX(-)	Common GRADAR	Transmitter pulse width.
SIGTY(-,-)	Common ECCHAF	Sigma for a particular type of chaff. Dimensioned 10, MRADFL (=4).
TIMEB	Argument	Time for calculations.
TIN(-)	Common ECCHAF	Drop times of parcels (sec). Dimensioned 30.
WVLTX(-)	Common GRADAR	Wavelength of ground radar transmitter (m).
XLOSS(-)	Common GRADAR	Correction loss factor.
XMT(-)	Argument	Transmitter position vector. Dimensioned 3.
XMTD(-)	Argument	Transmitter velocity vector. Dimensioned 3.
XSCT(-,-)	Common ECCHAF	X position of scatterers. Dimensioned 30, 5.
XV	Argument	Victim radar position, X coordinate (m).
XVDOT	Argument	Victim radar velocity, X component (m).
YSCT(-,-)	Common ECCHAF	Y position of scatterers. Dimensioned 30, 5.
YV	Argument	Victim radar position, Y coordinate (m).
YVDOT	Argument	Victim radar velocity, Y component (m).
ZSCT(-,-)	Common ECCHAF	Z position of scatterers. Dimensioned 30, 5.
ZV	Argument	Victim radar position, Z coordinate (m).
ZVDOT	Argument	Victim radar velocity, Z component (m).

TABLE 2.9-20b. Subroutine CHFSIG–Output Data.

Name	Source	Description
AREASK	Argument, Return from CLDSIZ	Chaff cloud cross sectional area as seen by the receiver (m2).
NUMPRO	Argument	Number of signals in signal processor.
RTSI(-)	Argument	Ranges of signals.
SGDOP(-)	Argument	Signal Doppler shifts.
SGDVA(-)	Argument	Signal azimuth channel voltages.
SGDVE(-)	Argument	Signal elevation channel voltages.
SGPCBW(-)	Argument	Pulse compression bandwidths.
SGPW(-)	Argument	Pulse widths of signals.
SGSV(-)	Argument	Sum channel voltages.

TABLE 2.9-21a. Subroutine CLDRCS–Input Data.

Name	Source	Description
DILEN(-)	Argument	Length of chaff dipole for each type. Dimensioned 9.
DIPNUM(-)	Argument	Number of chaff dipoles for each type. Dimensioned 9.
NTYPE	Argument	Number of chaff dipole types.
WAVEL	Argument	Wavelength (m).

TABLE 2.9-21b. Subroutine CLDRCS–Output Data.

Name	Source	Description
RCS	Argument	Chaff cloud RCS (m2).

TABLE 2.9-22a. Subroutine CLDSIZ–Input Data.

Name	Source	Description
AREAIL	Return from PAREA	Presented area of chaff cloud to illuminator.
KPARC	Argument	Actual number of chaff parcels expended.
RCV	Argument	Receiver position vector. Dimensioned 3.
XMIT	Argument	Transmitter position vector. Dimensioned 3.
XSCT(-,-)	Argument	X position of scatterers. Dimensioned 30, 5.
YSCT(-,-)	Argument	Y position of scatterers. Dimensioned 30, 5.
ZSCT(-,-)	Argument	Z position of scatterers. Dimensioned 30, 5.

TABLE 2.9-22b. Subroutine CLDSIZ–Output Data.

Name	Source	Description
AREAFT	Argument	Chaff cloud area as viewed from front.
AREAPB	Argument, Return from PAREA	Bistatic presented area of chaff cloud.
AREASK	Argument, Return from PAREA	Presented area of chaff cloud to receiver.

2.9.4 Assumptions and Limitations

Limitations on the chaff include the fact that the chaff rocket simulation is not presently operational. Other limitations involve the lack of the human operator impact on chaff effectiveness.

The chaff clouds are represented in a simplified geometrical model. The cloud is made up of a number of parcels dispensed up to the current time (KPARC), and each parcel is subdivided into five subparcels. The subparcels are randomly shifted with respect to the nominal center of the parcel, in order to incorporate some element of stochastic behavior in the dispersal of the chaff cloud. The parcels are approximated as rectangular shapes in order to simplify the computation of the projected area of the parcel presented to the illuminating source (ground illuminator or target-borne jammer for illuminated chaff) and to the receiver of energy scattered form the chaff.

It is uncertain at this time whether the ESAMS chaff model has enough fidelity to correctly model the effects on newer SAM systems that utilize more sophisticated signal processing such as coherent pulsed Doppler tracking.

ESAMS 2.7 has a number of ECCM techniques which may be employed by the threat systems. These will be covered in the tracking VSDRs. The impact of the ECCM techniques against the threats should be bounded through parametric studies.

The lack of a human operator could also affect the accurtacy of results using towed decoys. If deceptive jamming was detected, the operator could take actions to counter the jamming (switching to optical mode, etc.). Results evaluating the effectiveness of towed decoys should also be bounded through parametric studies to consider the impact of a man-in-the-loop.